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THE AVIATION POCKET-BOOK

1919-20

R. Borlase Matthews

ADVERTISEMENTS

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xii	- British & Colonial Aeroplane Co. Ltd. -	"Aviation, Filton"	Bristol 3906
vii	- Central Aircraft Co. -	"Aviduction, Phone, London"	Hampstead 4403-4
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xi	- Glendower Aircraft Co. Ltd. -	"Glenacelle, South-kens, London"	Kensington 7066
xxiii	- Grahame-White Aviation Co. Ltd. -	"Volplane, London"	Hyde, Kingsbury 120
xx	- Handley Page Ltd. -	"Hydrophid, Crickle, London"	Hampstead 7420
viii	- Hooper & Co. Ltd. -	"Sociable, London"	{ Regent 912 Kensington 4762
vi	- London Aircraft Co. -	"Zoomairera, Phone, London"	Dalston 3603-4
xxiv	- Martinsyde -	...	...
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xxv	- Robey & Co. Ltd. -	"Robey, Leeds"	Leeds 2 and 3
clv	- Roe, A. V., & Co. Ltd. -	"Senalpirt, Phone, London"	Gerrard 3186
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xxii	- Spencer, C. G., & Sons Ltd. -	"Aeronaut, London"	Dalston 1893
clvii	- Sturtevant Engineering Co. Ltd. -	"Sturtevant, London"	Central 7121
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xxi	- The First British and International Navigation Co. Ltd. -	...	Kensington 7063 (5 lines)
xv	- Vickers Ltd. -	"Vickerfyta, Knights, London"	Kensington 6520 (5 lines)
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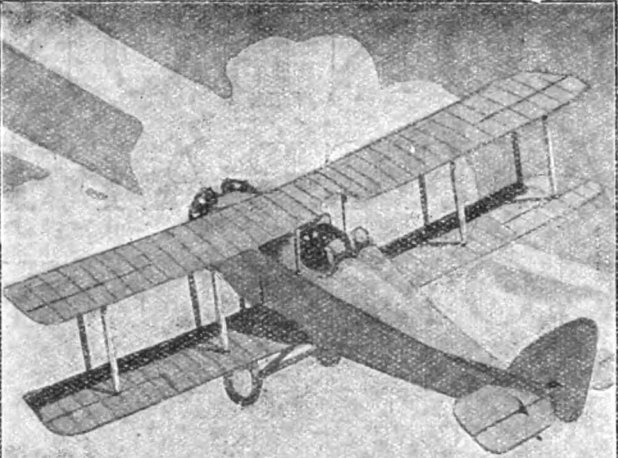
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AIRCRAFT

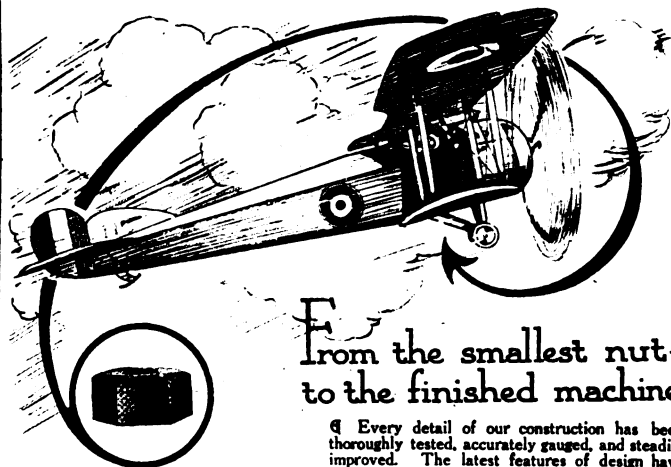
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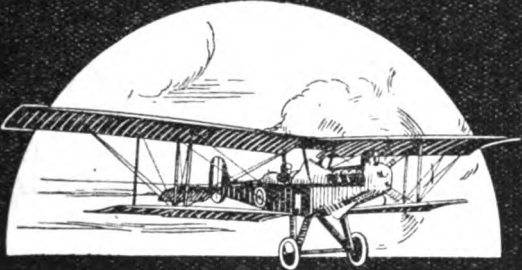
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BASIL STREET, KNIGHTSBRIDGE, S.W. 3**

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• (5 Lines)



Telegraphic Address—
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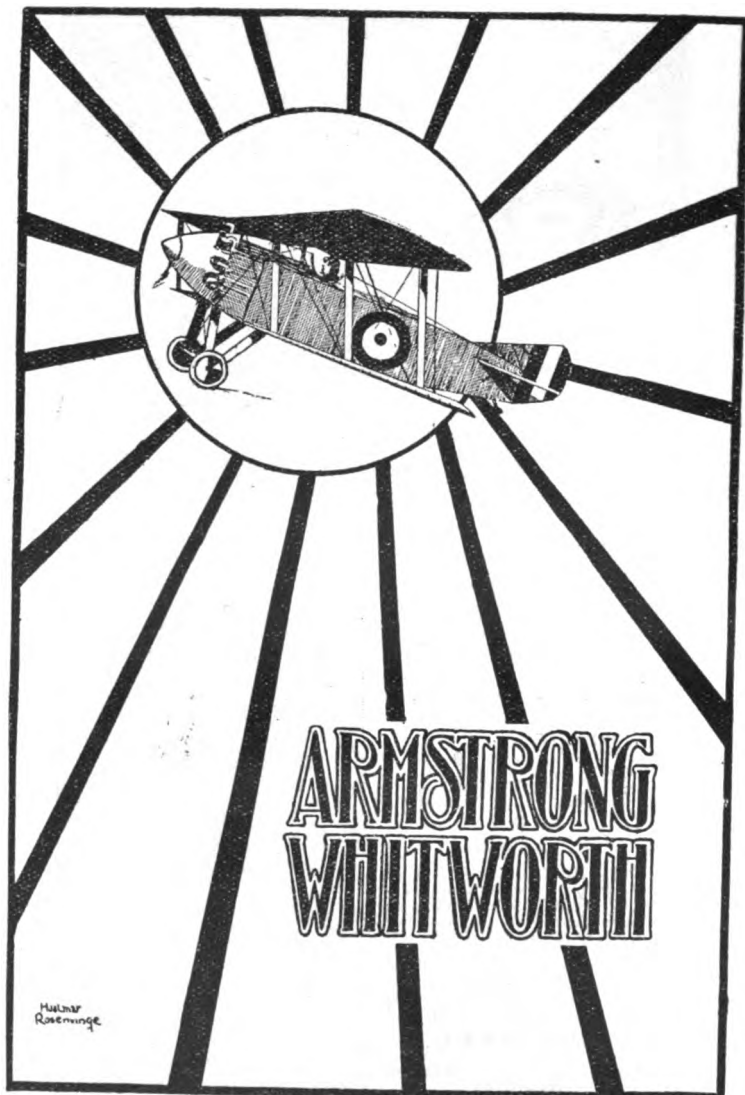
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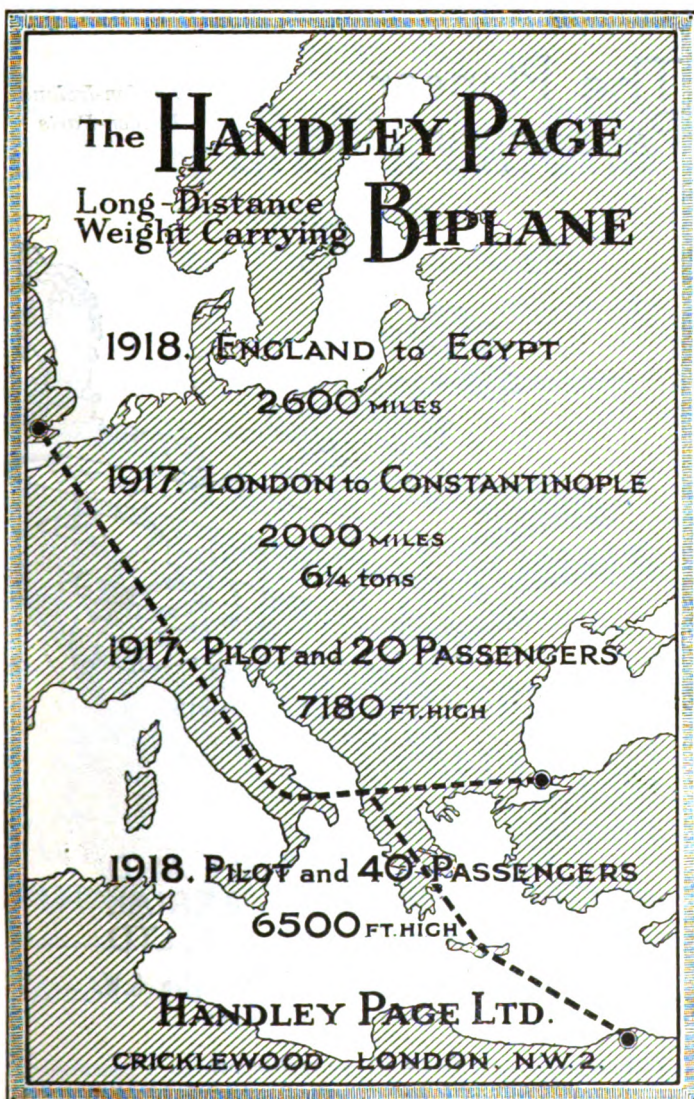
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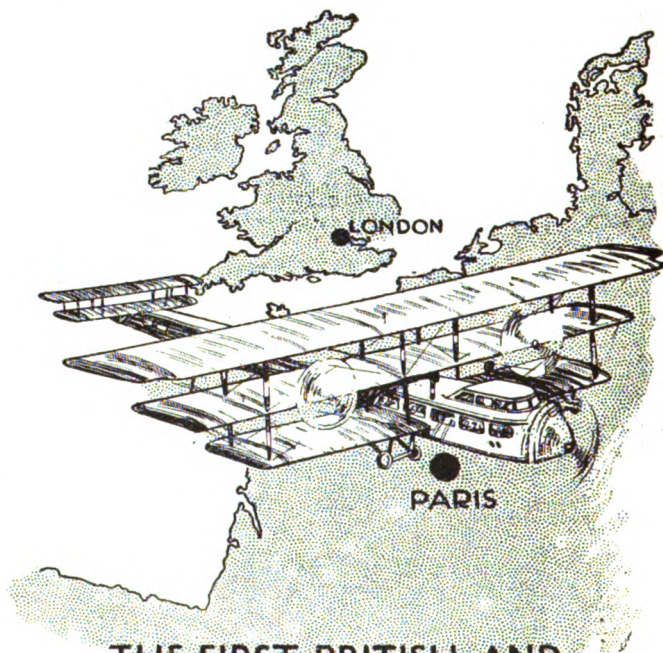
A map of Europe and North Africa is shown with a dashed line indicating flight routes. The route starts in England, goes to Egypt, then to Constantinople, and finally to a point in North Africa. The map is shaded with diagonal lines.

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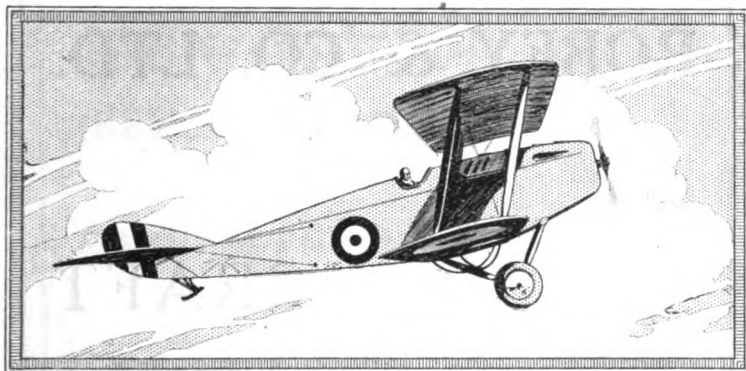
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THESE firms either make or supply parts and fittings for Aeroplanes and Airships—a most important department where expedition and promptitude are highly essential.

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xxxvi	Aero Mechanical Co. Ltd.	"Aerochanic, Sowest London"	Victoria 7570
xxxiv	Avery, W. & T., Ltd.	- "Avery, Birming- ham"	Smethwick 300
lxvii	Dermatine Co. Ltd.	- "Dermatine, Lon- don"	Hop 31
xxxi	E. R. Calthrop's Aerial Patents Ltd.	"Savemalivo, Ave., London"	London Wall 3266, 3267
cliii, cliv	Goldsmiths & Silver- smiths Company Ltd.	...	Gerrard 9091
i	Jones, A. E., Ltd.	- ...	...
xxxviii	Kinnell, C. R., & Co.	- ...	Hop 372
xxxii	Leo Ripault & Co.	- "Ripault, Reg., Lon- don"	Gerrard 7758
xxix, xxx	MacLennan, John, & Co.	"Vanduaara, Cent. London"	City 3115
xxxi	Moss, Wm.	- "Airobilmos, 'Phone, London"	Gerrard 6731
xxviii	Pritchett & Gold Ltd.	- "Storage, Sowest London"	Victoria 3181

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are favoured by
ALL FAMOUS PILOTS

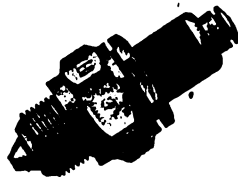
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FOR EVERY PURPOSE

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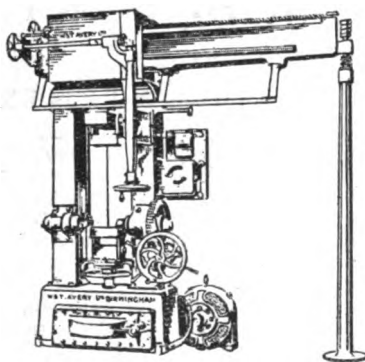
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M. A. S. RIACH

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CHAPTER IV.—BLADE SECTIONS, AND WORKING FORMULÆ.

CHAPTER V.—"LAYING OUT" THE AIR-SCREW.

CHAPTER VI.—STRESSES IN AIR-SCREW BLADES.

CHAPTER VII.—STATIC THRUST.

CHAPTER VIII.—EFFICIENCY OF AN AIR-SCREW AT DIFFERENT
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CHAPTER IX.—DIRECT LIFTING SYSTEMS.

APPENDIX I.

NOTE ON THE INFLUENCE OF "ASPECT RATIO."

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NOTE ON THE EFFECT OF THE INDRAUGHT IN FRONT OF AN
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" 7572

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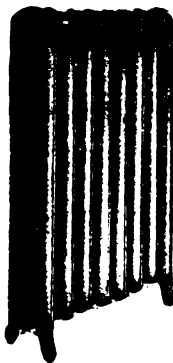
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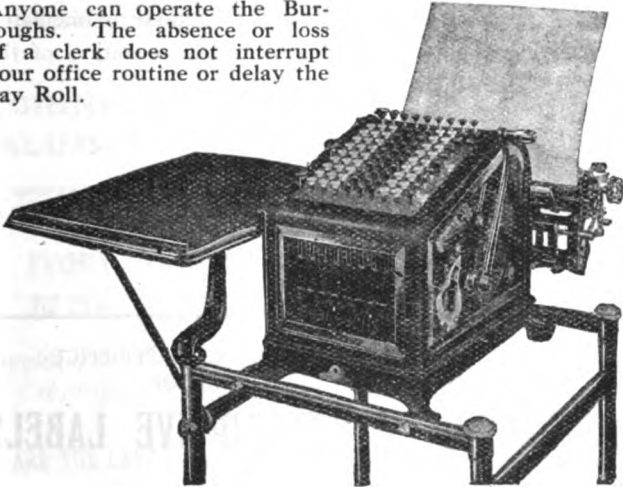
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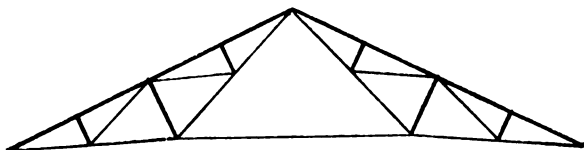
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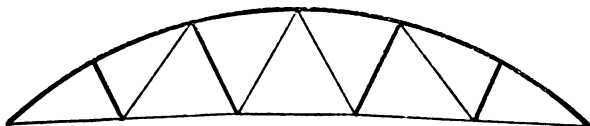
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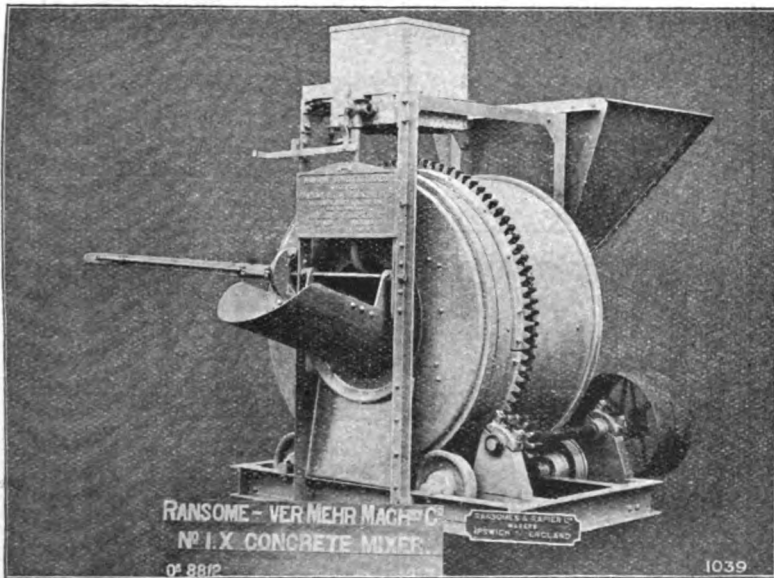
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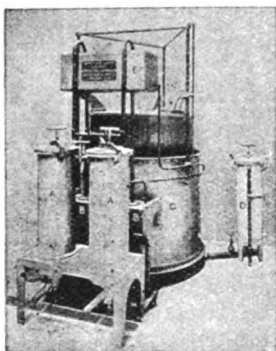
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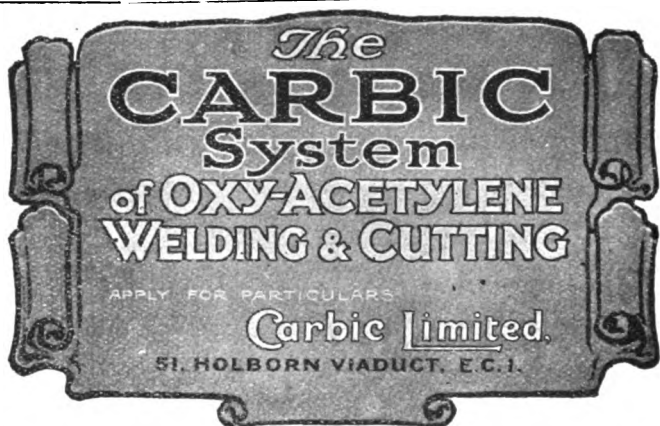
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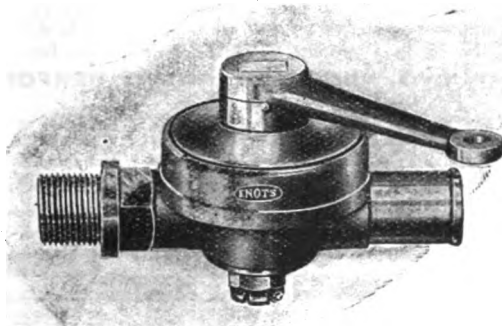
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 - XIV. ENGINE MOUNTINGS—Essential Requirements—Materials—Rotary Engine Mountings—Over-hung Mounting—Stationary Engine Mounting
 - XV. ERECTION AND ALIGNMENT—Accurate Part Production—Drilling of Bolt Holes—Locking of Bolts—Trueing of Main Planes—Fabric covering Planes—Fuselage Erection—Checking of Fuselage—Alignment of Complete Machine—Tension of Wires
- INDEX

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lxvii,

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Hop 31

lxviii

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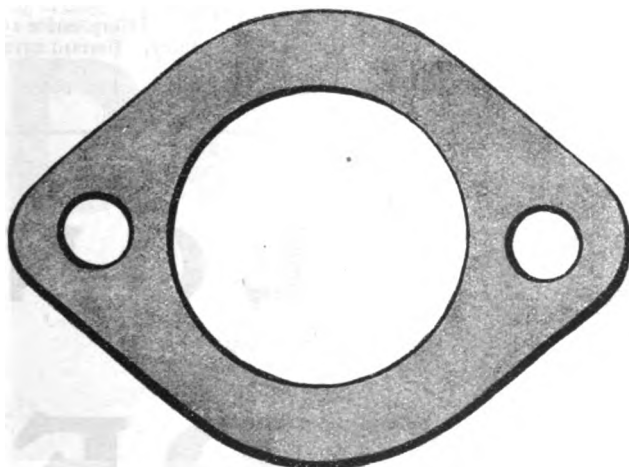
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DOPES, VARNISHES, GLUES, AND OILS

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lxxviii	Dixon's White Ltd. -	"..."	"..."
lxxv	Greenhill & Sons -	"Greenberg, London"	Central 1306
lxxx	Grove Chemical Co. Ltd.	"Crown, Appley Bridge"	Parbold 12
lxxxii	Ingham Clark, Robt., & Co. Ltd.	"Pearline, Westrand, London"	Regent 3923
lxxxiii	Mendine Co. - - -	"Mendinique, Cannon, London"	Bank 5873
lxxiv	Naylor Brothers (London) Ltd.	"Naylor, Southall"	Southall 30
lxxx	Nieuwhof, Surle & Co. Ltd.	"Suricodon, Fen, London"	Avenue 34 & 35
lxxi	Oldroyd, W., & Sons Ltd.	"Gelatine, Leeds"	Avenue 4978
lxxi	Premier Oil Extracting Mills Ltd. - - -	{ "Poem, Hull" "Premier, Hull"	{ Central Office 3990 to 3993 Corporation 1564
lxxvi	Titanine Ltd. - - -	"Tetrafree, Piccy, London"	Gerrard 2312
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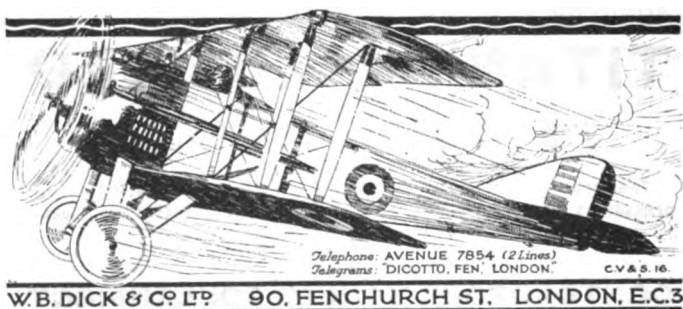
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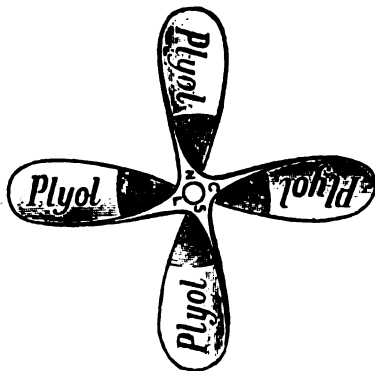
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PAGE	FIRM	TELEGRAMS	TELEPHONES
lxxxiii,	Johnson & Phillips	...	...
lxxxiv	Ltd.		



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(See next page)

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clvii	Sturtevant Engineering Co. Ltd.	"Sturtevant, London"	Central 7121
lxxxix	Walton Motors	...	...

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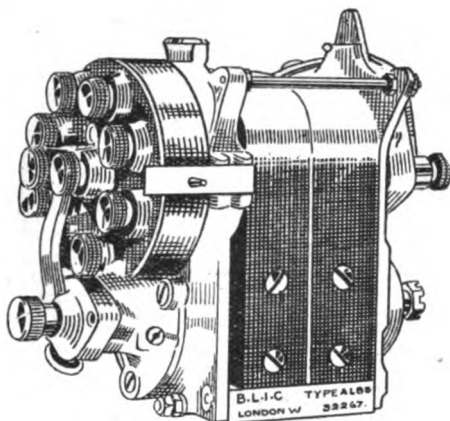
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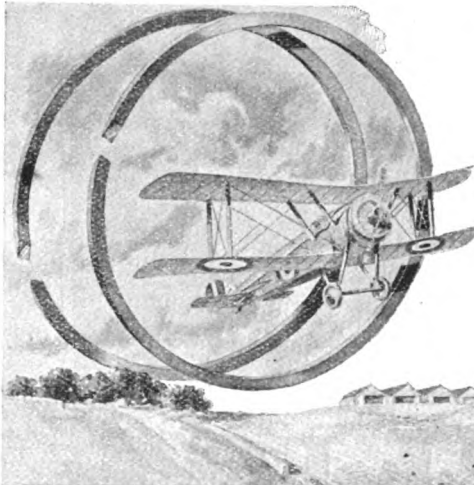
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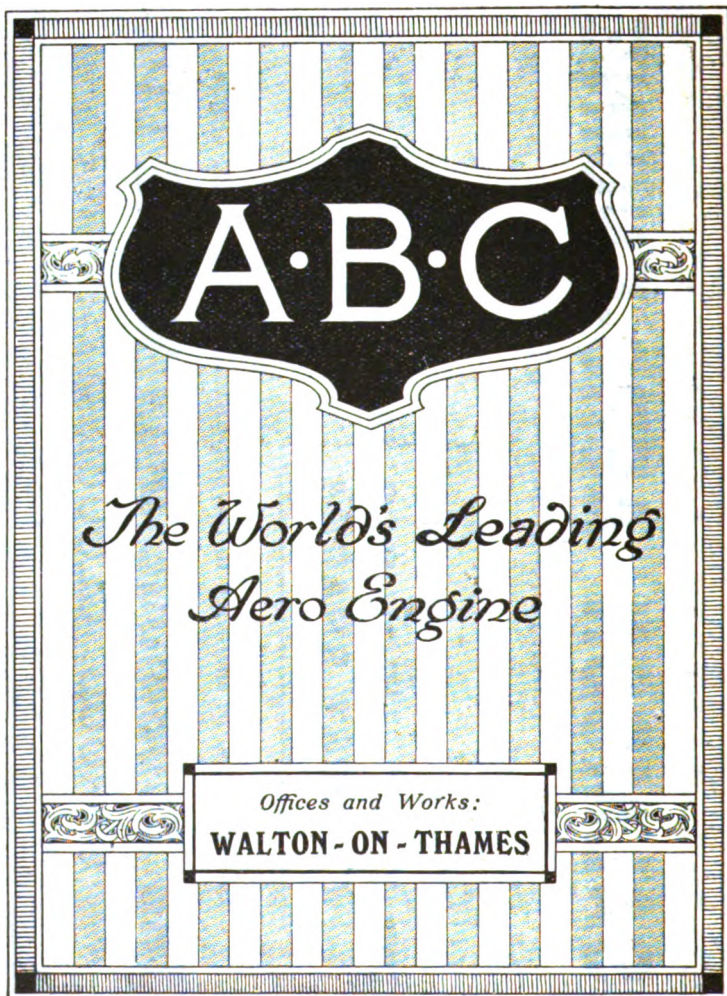
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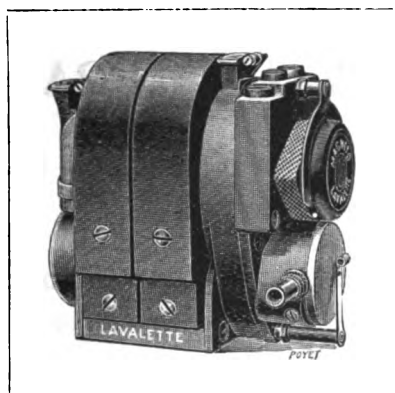
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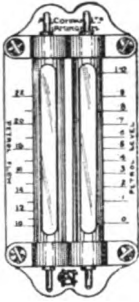
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PAGE	FIRM	TELEGRAMS	TELEPHONES
xcvi, cxii	Alexander, G. H.	- "Viking, Birming- ham"	Central 1918
xcvii	Hughes, H., & Son Ltd.	- "Azimuth, Fen, London"	Central 555
xcviii	Smith, S., & Sons	- "Speedomet, Lon- don"	Mayfair 6350
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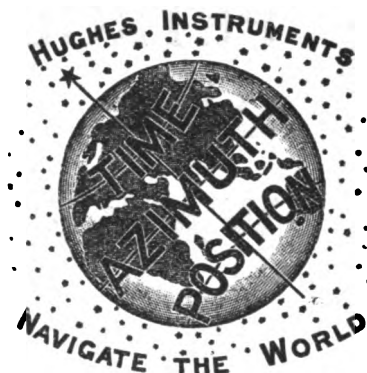
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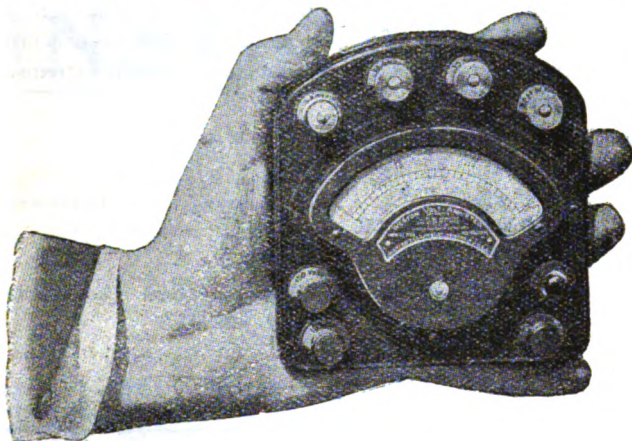
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PAGE	FIRM	TELEGRAMS	TELEPHONES
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cii	Insurance Agency Ltd.		
civ	Wheels and Wings Assoc. Ltd.	"Whewingal, Cannon, London"	Central 3982

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OF SCREW PROPULSION

BY

M. A. S. RIACH

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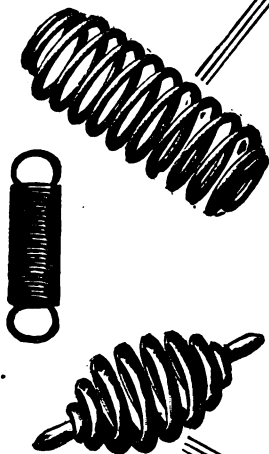
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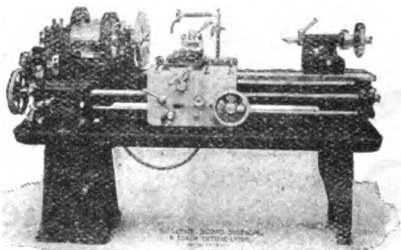
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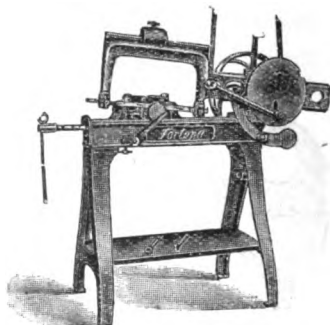
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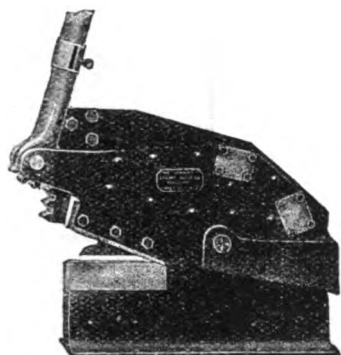
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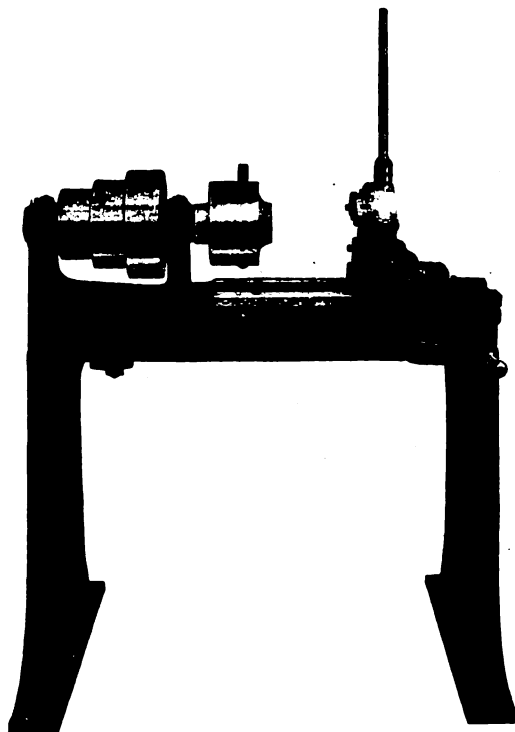
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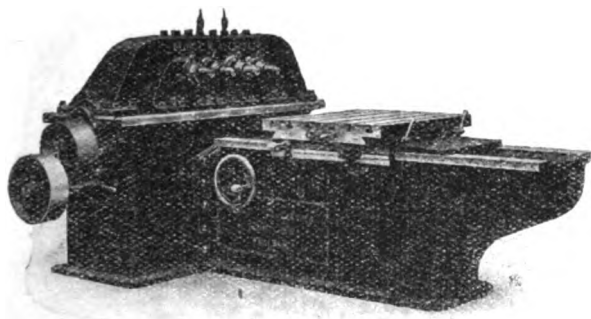
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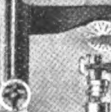
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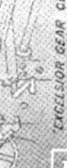
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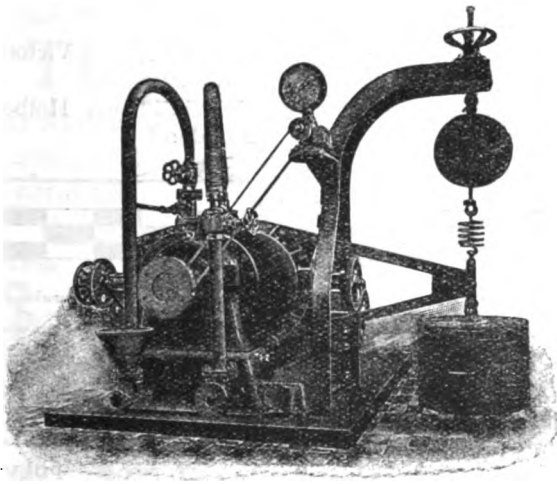
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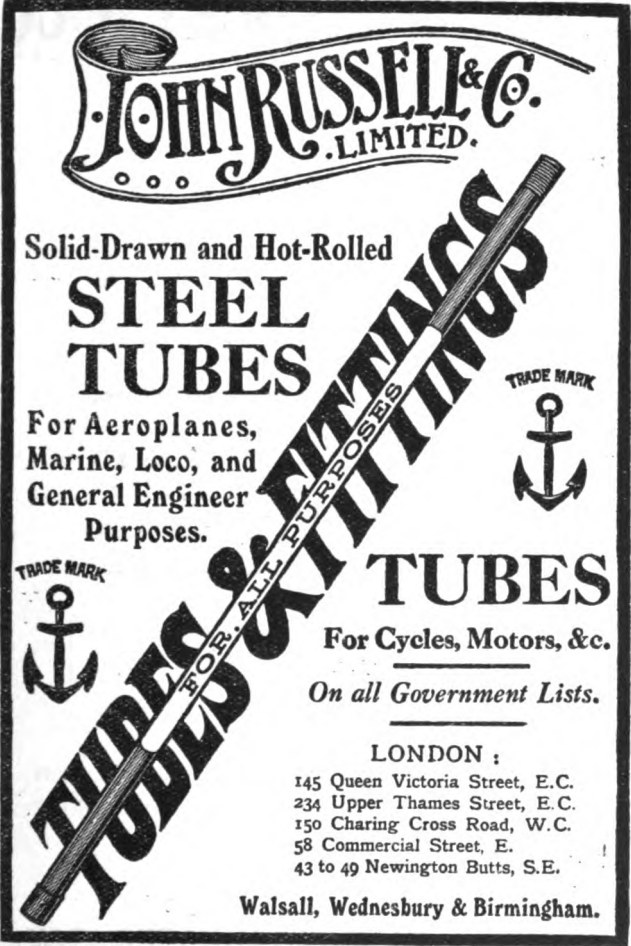
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Crepe de Chine, all Colours, 55/-, 3 for £8

We hold the largest stock of Pyjamas in London

All Pyjamas sent Post Free in U.K.

Height and Chest Measurement required

Swan & Edgar

The increasingly popular West End House. Estd. 1812

Piccadilly Circus, W. 1

When communicating with Advertisers please mention the Aviation Pocket-Book

FLIGHTS

LIMITED

ESTABLISHED 70 YEARS

**For Many Years
Specially Appointed
Military Outfitters**

TO THE

**PRINCIPAL
INFANTRY
REGIMENTS**

LONDON

4 NEW BURLINGTON STREET, W.1

Telegrams: "AFFLIGHTLY"

'Phone: REGENT 2346

WINCHESTER

HIGH STREET

'Phone No. 89

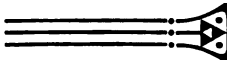
ALDERSHOT

HIGH STREET

'Phone No. 286

When communicating with Advertisers please mention the Aviation Pocket-Book

i

AIRMEN! 

DON'T PAY
FABULOUS PRICES
WHEN
THE BEST

Kit for Officers of Flying Services
MAY BE HAD
AT LOWEST RATES POSSIBLE
FROM

Specialists in Military Outfitting

MORRIS ANGEL & SONS
117 Shaftesbury Avenue
LONDON, W.C.

Inquiries Solicited ∴ Satisfaction Guaranteed

Telephone

Gerrard 5181

When communicating with Advertisers please mention the Aviation Pocket-Book

HOBSON & SONS (London) Ltd.**1, 3, and 5 Lexington Street****Golden Square****LONDON, W.1 (near Piccadilly Circus)****Telephone—Regent 56****ESTABLISHED 1850**

ROYAL AIR FORCE UNIFORMS A SPECIALITY

Actual Manufacturers of**ARMY AND NAVY UNIFORMS****ACCOUTREMENTS****HELMETS AND CAPS****GOLD LACE AND EMBROIDERY**

S.E. Branch—**154/164 Tooley St., London Bridge, S.E.1****'Phone—Hop 680****W.C. Branch—****27 Maiden Lane, Bedford St., Strand, W.C.2****(Pipe & M'Gill Ltd.)****'Phone—Gerrard 3657***When communicating with Advertisers please mention the Aviation Pocket-Book*

Telephone: 13170 Central

GLEN & :: :: POWELL Ltd.

H. GLEN
A. J. POWELL } Formerly with Miller & Son
M. C. CARTER }

Service Outfitters

to the

*R.A.F., R.N., R.N.R.
Mercantile Marine*

*INDIAN AND COLONIAL OUTFITS
CADETS COMPLETELY EQUIPPED*

EXACTLY OPPOSITE FENCHURCH STREET STATION
London Street, E.C. 3, and at Tilbury Docks
(End of Footbridge)

When communicating with Advertisers please mention the Aviation Pocket-Book



Where Flying Men are Fitted Out

SPECIALISTS, from the earliest motoring days, in garments which are wind-proof and weather-proof under the most trying conditions, Messrs DUNHILLS have become the House for KIT FOR OFFICERS OF THE FLYING SERVICES.

Their Kit is famous for superlative quality and durability, combined with a sweet reasonableness in price.

Call in, if you can, at our well-known "Base" in Conduit Street—a few paces from Regent Street—and inspect the show of Kit; or, if London is "out of bounds," drop a line for patterns and further particulars, which will be sent gladly on request.

Dunhill's Limited
2 Conduit Street, Regent Street, W. 1
GLASGOW - 72 St Vincent Street

When communicating with Advertisers please mention the Aviation Pocket-Book

SEWING MACHINES

THE amount of fabric required daily for aircraft is phenomenal. Incidentally, this fabric has to be sewn, but it is not generally known that this sewing is largely accomplished by special sewing machines of clever design, which have been evolved to accomplish this special work.

PAGE

FIRM

TELEGRAMS

TELEPHONES

cxxxvii, **Singer Sewing**
cxxxviii **Machine Co. Ltd.**

...

City 8510

SINGER

SEWING MACHINES FOR AIRCRAFT

A Post Card or Letter to either of the undermentioned Addresses will receive prompt attention.

SINGER SEWING MACHINE Co. LTD.
MANUFACTURING TRADE DEPARTMENTS

BELFAST—43 Queen Street
BIRMINGHAM—93 Station Street
BRISTOL—87 Victoria Street
DUBLIN—69 Grafton Street
GLASGOW—67 Queen Street
LEEDS—36 Trinity Street

LEICESTER—82 High Street
LIVERPOOL—21 Bold Street
LONDON—17 Chiswell Street, E.C.1
MANCHESTER—8 Newton Street
NORWICH—16 Calvert Street
NOTTINGHAM—60 Long Row West

When communicating with Advertisers please mention the Aviation Pocket-Book

SINGER SEWING MACHINES FOR AIRCRAFT

WE supply an extensive range of specially designed machines for use in the various stitching operations connected with Airships, Aeroplanes, Balloons, Hangars, etc. etc.

Full particulars supplied on application



52W100 Machine

Fitted with 2 Needles, with or without Lapseam Feller

This Machine has a special feeding device for producing a perfectly uniform seam. It has ample space under the arm to accommodate broad widths of seamed fabrics

The experience of our Staff of
Experts is always at your disposal

SINGER SEWING MACHINE Co. Ltd.

Central Agency for the Manufacturing Trade
17 Chiswell Street, FINSBURY, LONDON, E.C.1

For full list of Manufacturing Trade Departments see opposite page

When communicating with Advertisers please mention the Aviation Pocket-Book

LODGE SPARKING PLUGS

THESE may be termed the Soul of the Engine; if they fail, all fails. Of all things, therefore, it is of especial importance to employ selected materials of the highest quality in their manufacture, and to construct them in the best possible manner.

PAGE CXXXIX,	FIRM Lodge Sparking Plug Co. Ltd.	TELEGRAMS "Igniter, Rugby"	TELEPHONES Rugby 235
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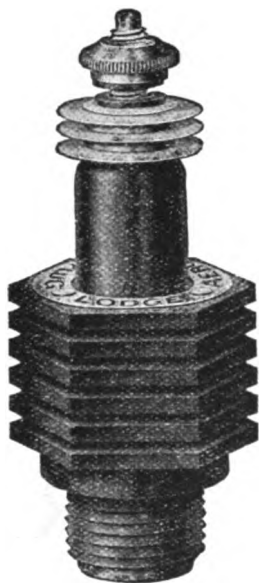
LODGE

AIRCRAFT PLUGS



Made In England
 by
THE LODGE SPARKING PLUG CO., LTD.,
RUGBY

When communicating with Advertisers please mention the Aviation Pocket-Book



THE ACE OF PLUGS

When communicating with Advertisers please mention the Aviation Pocket-Book

SPRAY PAINTING

MANY old-fashioned processes are disappearing under the influence of urgent demand for quicker and yet quicker production. Among them is hand painting. Whether it be the painting of the instruction charts employed to educate prospective aviators, or parts of the actual aeroplane itself, the mechanical spray painter is coming into its own.

PAGE

FIRM

TELEGRAMS

TELEPHONES

cxli, **Aerograph Co. Ltd.** - "Aerography, Holborn 2041
cxlii London"

THE
(Reg. Trade)

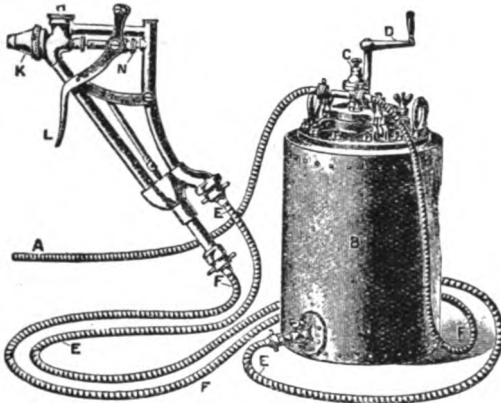
AEROGRAPH

(Mark)

is now used everywhere for Painting, Varnishing, Lacquering, etc. It saves much time and gives better results.

Q. If you cannot come to us to see a demonstration send us your articles to be painted or lacquered, and let us show you the results and tell you the time it takes to do.

When communicating with Advertisers please mention the Aviation Pocket-Book



THIS ILLUSTRATION SHOWS

THE AEROGRAPH

as arranged for spraying Dope, Oil Paints, or other heavy compositions.

The control is so perfect that the same hand piece will paint a shilling piece without waste, or will paint three square yards per minute.

No spray is an Aerograph except our own manufacture.

THE AEROGRAPH CO. LTD.
43 HOLBORN VIADUCT, LONDON, E.C. 1

When communicating with Advertisers please mention the Aviation Pocket-Book

TELEPHONES

FROM the intercommunication instrument on board the aircraft to the equipment on the aerodrome, the telephone is becoming indispensable.

PAGE cxliii, Telephone Manufac- cxliv turing Co. Ltd.	FIRM 	TELEGRAMS "Bubastis, Dulcrox, London"	TELEPHONES Sydenham 1067
---	--------------	---	--------------------------------

AUTOMATIC INTERCOMMUNICATING TELEPHONES

Enable you to speak from your desk to all departments of your business without a moment's delay; also any department can speak direct to any other. They speed up production, save you much valuable time—and pay for themselves over and over again. Hundreds of large firms use them ——— and testify to their efficiency ———

The Telephone Manufacturing Co. Ltd.
West Dulwich, London, S.E.21

Telephone: Sydenham 1067

Telegrams: "Bubastis, Dulcrox"

When communicating with Advertisers please mention the Aviation Pocket-Book



QUALITY

TELEPHONE APPARATUS

The large and successful business we have built up in the past is ample proof of the merit and reliability of

NEW SYSTEM TELEPHONES

Install a system of our intercommunicating 'Phones for an immediate connection between Offices, Works, Shipyards, Foundries, and Warehouses

WRITE TO-DAY for particulars of our rental service

The Telephone Manufacturing Co. Ltd.

Telephone: Sydenham 1067 West Dulwich, London, S. E. 21 Telegrams: Bubastis, Dulcrox

When communicating with Advertisers please mention the Aviation Pocket-Book

TRANSPORT

WHEN out of its element—the air—an aeroplane is an unwieldy thing to transport, especially as it is so light and fragile. Hence new means and methods have had to be evolved for the safe and speedy transport of these machines by road. Incidentally the best of organisation is necessary to carry out such work properly.

PAGE	FIRM	TELEGRAMS	TELEPHONES
cxlv,	Pickfords Ltd.	...	Brixton 2277
cxlvi			

ROAD TRANSPORT

PICKFORDS LTD.

96 HACKFORD ROAD, S.W.9

'Phone 2277-2278 Brixton

Pioneers of the Aircraft Transport by Motor

When communicating with Advertisers please mention the Aviation Pocket-Book

PICKFORDS LTD.
96 HACKFORD ROAD
S.W. 9

'Phone 2277-2278 Brixton

WE can supply Motors and
Trailers for the convey-
ance of

AEROPLANES,
SEA PLANES,
FLYING HULLS,
& SPARE PARTS

to any part of the Country, by the
Day, Week, Month, or the Year,
or on Mileage Basis

When communicating with Advertisers please mention the Aviation Pocket-Book

TYRES AND WHEELS

NO one looking at an Aeroplane seven years ago would have imagined that the future would affect the Tyre industry ; but a momentary consideration as to the thousands of machines being built brings about a realisation of the present state of affairs and the necessity for the maintenance of a high standard of quality.

PAGE	FIRM	TELEGRAMS	TELEPHONES
cl	North British Rubber Co. Ltd.	...	...
cxlviii	Palmer Tyre Ltd.	- "Tyricord, West- cent, London"	Gerrard 1214

**Early application for Advertisement
space in future Editions of this
Work should be made to :**

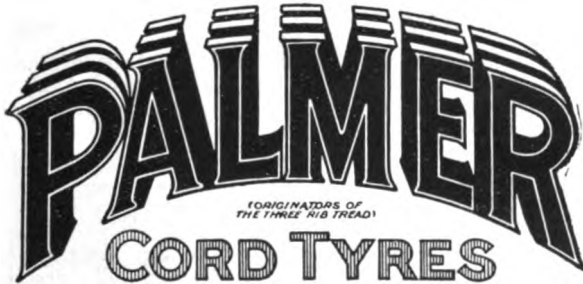
**CROSBY LOCKWOOD & SON
7 STATIONERS' HALL COURT, LONDON, E.C. 4**

When communicating with Advertisers please mention the Aviation Pocket-Book

Every Tin of Petrol carries you Ten per cent. farther

and in addition you get more tyre miles for every sovereign spent if you motor on Palmer Tyres. ¶ The unique Cord foundation of the Palmer positively ensures the 10% petrol saving, and the tough rubber tread makes possible the greater mileage per cover on the road.

Send for our booklet, "Palmers, Petrol, and Power," and by studying the diagrams, prove for yourself that the above is no mere advertising talk, but that it is established by positive proof.



THE PALMER TYRE LTD.

119, 121, 123 Shaftesbury Avenue
LONDON, W.C.

When communicating with Advertisers please mention the Aviation Pocket-Book

k

NEW BOOKS

ON

Aviation Subjects



THE AIRCRAFT IDENTIFICATION BOOK

A Concise Guide to the recognition of Different Types and Makes of all kinds of Aeroplanes and Airships. By R. BORLASE MATTHEWS, Wh.Ex., A.M.I.C.E., M.I.E.E., F.R.A.S. (Author of the "Aviation Pocket-Book.") With numerous Illustrations. Crown 8vo. Just Published. 3s. 6d. net.

AVIATION ENGINES

Their Design, Construction, Operation and Repair. A Book for the Student, Engineer, and all interested in Aviation. Giving Practical Instruction on Repair and Maintenance. By Captain VICTOR W. PAGÉ, of the U.S.A. Air Service. 580 pages, with over 240 Illustrations. Medium 8vo. 16s. net.

A.B.C. OF AVIATION

A Non-Technical Manual for all Students of Aircraft. By Captain VICTOR W. PAGÉ, Sig., R.C.A.S. Just Published. Demy 8vo. 257 pages, numerous Illustrations. 12s. 6d. net.

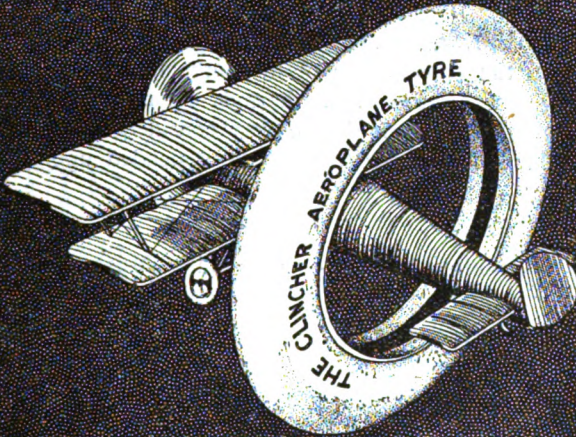
GASOLINE AND KEROSENE CARBURETTORS

A Simple Comprehensive Treatise for Practical Men. All the latest Types of Carburettors fully described. By Captain VICTOR W. PAGÉ, M.S.A.E. Crown 8vo. 206 pages, profusely Illustrated. 8s. 6d. net.

London: Crosby Lockwood & Son

7 Stationers' Hall Court, E.C., and 5 Broadway, Westminster, S.W.

When communicating with Advertisers please mention the Aviation Pocket-Book



CLINCHER

Aeroplane

TYRES

"CLINCHER" Aeroplane Tyres
are specially constructed to withstand
great shock and side strain on alighting
Made at Castle Mills, Edinburgh
The Empire's Largest Rubber Factory

The North British Rubber Co. Ltd. Edinburgh. London Branches.

When communicating with Advertisers please mention the Aviation Pocket-Book

WIRE ROPES, CORDS, CABLES, AND RIGGING

THESE are among the most important features in the construction of an Aeroplane, and the life of an aviator often depends upon their reliability. The following firms devote very considerable care to the production of goods that can be depended upon.

PAGE	FIRM	TELEGRAMS	TELEPHONES
clii	Bruntons	- - "Wiremill, Musselburgh"	28
clx	Bullivant & Co. Ltd.	"Bullivant, Fen, London"	Avenue 2108

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space in future Editions of this
Work should be made to :

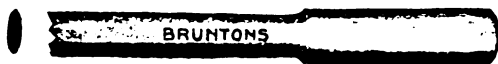
CROSBY LOCKWOOD & SON
7 STATIONERS' HALL COURT, LONDON, E.C. 4

When communicating with Advertisers please mention the Aviation Pocket-Book

WIRE STAY RODS
FLEXIBLE WIRE ROPES
AND STRANDS - - -
FITTINGS & FASTENINGS
FOR AVIATION PURPOSES



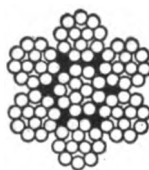
Round



Streamline



Special Tempered Wire



**ORIGINAL MAKERS OF
STREAMLINE WIRES**

BRUNTONS
MUSSELBURGH, SCOTLAND

When communicating with Advertisers please mention the Aviation Pocket-Book



Service Watches for Aviators



The Goldsmiths & Silversmiths Company's Watches are of first quality and will be found to be reliable and accurate in service. A Catalogue will be posted free on application.

The Military Watch illustrated has luminous hands and figures and a dust and damp proof screw-in case.

Half Hunter Cover (illustrated)	-	£5. 7s. 6d.
Full Hunter Cover	- -	£5.
Open Face	- - -	£4. 10s.

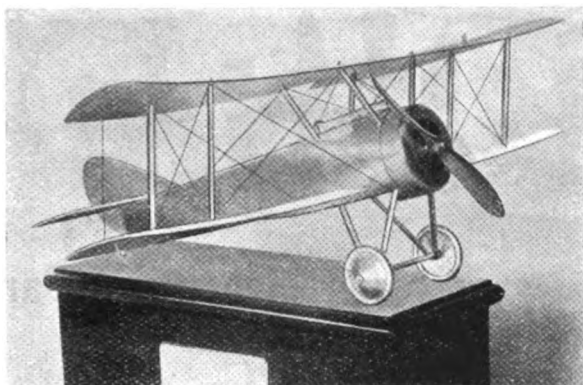
Prices are subject to alteration without notice

THE
GOLDSMITHS & SILVERSMITHS
COMPANY LTD.
*with which is incorporated
The Goldsmiths Alliance Ltd. Estd 1751*

Only one Address ∴ No Branches

112 Regent Street, London, W.1

When communicating with Advertisers please mention the Aviation Pocket-Book



Silver Models

THIS Silver Model was made by the Goldsmiths & Silversmiths Company for presentation purposes at a public function. It is a replica of a British Machine, and it shows with what skill and accuracy the Company's models are produced.

Models can be prepared from the original or from Photographs.

Estimates and designs will be submitted free on application.

THE
GOLDSMITHS & SILVERSMITHS
COMPANY LTD. *with which is incorporated*
The Goldsmiths Alliance Ltd. Est. 1753

Jewellers to H.M. The King

112 Regent Street, London, W.1

When communicating with Advertisers please mention the Aviation Pocket-Book



AVRO is the brilliant name in Aeroplane and Seaplane construction.

It is a guarantee of Quality in the manufacture of Flying Machines of every description.

The AVRO Aeroplane is efficient because it is designed on scientifically sound principles and built of the best materials with the utmost skill and care.

Efficiency is an AVRO feature that commends itself to mechanic and pilot alike.

It is just one of the many factors that make the AVRO the premier flier and the ideal training machine.

A. V. ROE & CO. LTD.

DESIGNERS AND CONSTRUCTORS OF
AEROPLANES AND ACCESSORIES

Manchester :: Southampton
and 166 Piccadilly, London, W. 1

Telephone: Gerrard 3186

When communicating with Advertisers please mention the Aviation Pocket-Book

THE AVIATION POCKET-BOOK
FOR 1919-20



For Ventilating and Heating

Aeroplane Works, Dope Shops, and Airship Sheds—install the Sturtevant System. It both ventilates and warms by distributing an abundance of warm air through a system of ducts to every part of the building. In the summer, when ventilation only may be required, the heating unit can be shut off.

Consult us on your requirements, we have successfully equipped over 90 Aircraft Works with our systems, and shall be pleased to advise you.

Specialists also in the drying of Aeroplane Timber, Wood Refuse, and Dust Collecting—Forges and Forge Plants—All kinds of Fans, Blowers, and Exhausters.

Ask for General Catalogue, and mention "Aviation Pocket-Book."

Sturtevant

Engineering Co. Ltd.

147 Queen Victoria Street, London, E.C.4

When communicating with Advertisers please mention the Aviation Pocket-Book

THE AVIATION POCKET - BOOK FOR 1919-20

A COMPENDIUM OF MODERN PRACTICE AND
A COLLECTION OF USEFUL NOTES, FORMULÆ,
RULES, TABLES, AND DATA RELATING TO
AERONAUTICS

By

R. BORLASE MATTHEWS

ASSOCIATE MEMBER OF THE INSTITUTION OF CIVIL ENGINEERS

MEMBER OF THE INSTITUTION OF ELECTRICAL ENGINEERS

FELLOW OF THE ROYAL AERONAUTICAL SOCIETY

WHITWORTH EXHIBITIONER



Seventh Edition, Revised and Enlarged

LONDON

CROSBY LOCKWOOD AND SON

7 STATIONERS' HALL COURT, LUDGATE HILL, E.C. 4, AND

5 BROADWAY, WESTMINSTER, S.W. 1

CALENDAR NOTES, 1917-1920.

	1917	1918	1919	1920	
January 1	M	Tu	W	Th	These notes may be usefully employed to find out quickly, and with the minimum amount of calculation, on what day of the week any particular day of the month may fall. <i>e.g.</i> , 2nd May 1919 will fall on a Friday, because from the table 1st May is indicated as falling on a Thursday, etc.
February 1	Th	F	S	S	
Ash Wed.	Feb. 21	Feb. 13	Mar. 5	Feb. 13	
March 1	Th	F	S	M	
April 1	S	M	Tu	Th	
Good Fri.	Ap. 6	Mar. 29	Ap. 18	Ap. 2	
East. Mon.	" 9	Ap. 1	" 21	" 5	
May 1	Tu	W	Th	S	
Whit. Mon.	May 28	May 20	June 9	May 24	
June 1	F	S	S	Tu	
July 1	S	M	T	Th	* The number of years elapsed of the 19 year Lunar cycle.
August 1	W	Th	F	S	† The age of the moon on New Year's day.
Aug. Bk. H.	6	5	4	2	‡ The number of years elapsed of the 28 year Solar cycle.
September 1	S	S	M	W	§ The day of the month of the first Sunday in January.
October 1	M	Tu	W	F	(The characters A, B, C, D, E, F, and G represent respectively 1, 2, 3, 4, 5, 6, and 7.)
November 1	Th	F	S	M	¶ Leap Year, 1920.
Adv. Sun.	Dec. 2	Dec. 1	Nov. 30	Nov. 28	
December 1	S	S	M	W	
Chr. Day	Tu	W	Th	S	
* Golden No.	18	19	1	2	
† Epoch	6	17	29	10	
‡ Solar Cycle	22	23	24	25	
§ Dom. Letter	G	F	E	DC ¶	
¶ 1st S in Jan.	7	6	5	4	

NEW POSTAL RATES (in force from 3rd June 1918).

DESCRIPTION.	POSTAL RATES.				PRINTED PAPER RATES.	
	Inland.	Colonial and U.S.A.	H.M. Ships and Forces Abroad.	Foreign.	Inland.	Foreign.
Postcards	d 1	d 1	d 1	d 1	d ..	d ..
Letters or Packets of weight not exceeding						
1 oz. 28 gms.	1½	1½	1	2½	1½	1½
2 oz. 56 gms.	1½	2½	1½	4	1	1½
4 oz. 93 gms.	1½	4½	1½	7	1½	1
6 oz. 168 gms.	2	6½	2	10	2	1½
8 oz. 227 gms.	2½	8½	2½	13	2½	2
10 oz. 283 gms.	3	10½	3	16	3	2½
Each additional	1 oz. 28 gms.	1	1	1½	..	..
2 oz. 56 gms.	½	2	½	3	½	1

Inland Parcels { Not exceeding 3 lbs. in weight 6d.
 { Exceeding 3 lbs., but not exceeding 7 lbs. 9d.
 { Exceeding 7 lbs., but not exceeding 11 lbs 1s.

The Inland Newspaper Rate is ½d. per paper regardless of the weight. Inland Packages not exceeding 1½ lbs. (20 oz. or 567 grams) in weight can be sent by letter post more cheaply than by parcel post.

How to Estimate the Weight of a Postal Packet, etc.

Six sheets of quarto (8 in. by 10 in.) letter paper and an ordinary small envelope, stamped complete, weigh just under an ounce. A round of ammunition, or 3 pennies, or 5 shillings, or 5 halfpennies (English or French) weigh one ounce.

A halfpenny is one inch in diameter. Ten penny diameters are the equivalent of one foot.

(For Calendar, see p. vii.)

PREFACE TO THE SEVENTH EDITION

ONCE again it has been found practicable to re-write a very considerable portion of this book, and also to increase its size, so that it may be as up to date as possible, and of maximum value to its readers. The limitations put upon an author who has to deal with technical subjects of this nature are not as restricted as they were, now that the armistice has been declared. It must, however, be borne in mind that the present revision was practically completed before the cessation of hostilities.

Reference to the new features and the general basis of the arrangement of this book will be found in the Foreword on p. xiii. It will be observed that a very radical departure has been taken in this 1919-20 edition, in that (*a*) the International Decimal Classification System has been adopted, and (*b*) it has been printed in accordance with methods (the DE-tachable DA-ta System) patented by the Author, so that any or all the contents can be detached and inserted in a loose leaf book, according to the particular needs of the purchaser.

The Author wishes to acknowledge the kind assistance of those who have offered suggestions for the improvement of the book, and in particular that of Mr W. B. Esson, M.I.C.E., M.I.E.E., past president of the Society of Civil and Mechanical Engineers; Sir W. Napier Shaw, D.Sc. (Meteorology); Professor P. Groom (Timber); Lieut. Frank Thomas (A.G.S. parts); Capt. J. Morris (Rigging); Capt. P. Beer (Engines); Capt. A. F. C. Pollard (Decimal Classification); Capt. C. W. Alexander (Structural Design); Mr J. D. North; Capt. Lange (French Glossary).

Any suggestions from readers for the improvement of the work will be much appreciated.

R. BORLASE MATTHEWS.

GREATER FELCOURT,
EAST GRINSTEAD, 1919.

v

420878

PREFACE TO THE FIRST EDITION

THANKS to the courtesy of Count Henri de la Vaulx, Member of the Official French Aero Commission and, for many years, holder of the world's record for long distance ballooning, the Author was privileged to be present on the memorable occasion when the late Wilbur Wright, for the first time in history, flew with a passenger for over an hour in an aeroplane. This feat was accomplished as recently as 1908, and the great progress that has been made since is very remarkable. The Royal Aero Club alone has granted about 300 pilots' certificates, and this is a very small number compared with the certificates issued abroad.

When examining Wilbur Wright's biplane—then the only really successful flying machine in the world—it was brought home to the Author that it represented certain principles of construction which were arrived at as the result of elimination by trial and error, and with the aid of mathematical research. This was further emphasised by observations made as the result of attendance at the world's first aviation meeting at Rheims, and the first Aero Exhibition at Paris; and thus led to a collection of data which would enable an analysis of the principles to be made.

Such information undoubtedly being of great value and assistance to all interested in the art and principles of aviation, it was arranged in the present form of a Pocket-Book. Owing to the rapid advance of the art, it was naturally difficult to select the most useful matter out of the very considerable mass of data which has accumulated; however, the choice has been carefully made. The Author has avoided, as much as possible, the introduction of mathematical matter, and also any information contained in other pocket-books, so that this little volume should serve as a companion or supplement to standard mechanical engineering books of reference, as well as a general *vade mecum*.

R. BORLASE MATTHEWS.

SWANSEA, 1912.

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1975, 1980,

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EMBER

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17	18	19	20
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Also the calendar for the years 1824, 1852, 1880, 1948 and 1976.

PREFACE TO THE FIRST EDITION

THANKS to the courtesy of Count Henri de la Vaulx, Member of the Official French Aero Commission and, for many years, holder of the world's record for long distance ballooning, the Author was privileged to be present on the memorable occasion when the late Wilbur Wright, for the first time in history, flew with a passenger for over an hour in an aeroplane. This feat was accomplished as recently as 1908, and the great progress that has been made since is very remarkable. The Royal Aero Club alone has granted about 300 pilots' certificates, and this is a very small number compared with the certificates issued abroad.

When examining Wilbur Wright's biplane—then the only really successful flying machine in the world—it was brought home to the Author that it represented certain principles of construction which were arrived at as the result of elimination by trial and error, and with the aid of mathematical research. This was further emphasised by observations made as the result of attendance at the world's first aviation meeting at Rheims, and the first Aero Exhibition at Paris; and thus led to a collection of data which would enable an analysis of the principles to be made.

Such information undoubtedly being of great value and assistance to all interested in the art and principles of aviation, it was arranged in the present form of a Pocket-Book. Owing to the rapid advance of the art, it was naturally difficult to select the most useful matter out of the very considerable mass of data which has accumulated; however, the choice has been carefully made. The Author has avoided, as much as possible, the introduction of mathematical matter, and also any information contained in other pocket-books, so that this little volume should serve as a companion or supplement to standard mechanical engineering books of reference, as well as a general *vade mecum*.

R. BORLASE MATTHEWS.

SWANSEA, 1912.

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41	10	charge	" "	change
41	11	forms	" "	force
41	27	if	" "	of
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44	22	BDC 50°	" "	BDC to 50°
44	23	BDC 35°	" "	BDC to 35°
45	24	TDC...15°	" "	TDC to 15°
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Also the calendar for the years 1824, 1852, 1880, 1948 and 1976.

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R. BORLASE MATTHEWS.

MANSE, 1912.

vi

CALENDAR FOR 1919.

OCTOBER							NOVEMBER							DECEMBER						
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
...	...	...	1	2	3	4	...	...	...	...	...	...	1	...	1	2	3	4	5	6
5	6	7	8	9	10	11	2	3	4	5	6	7	8	7	8	9	10	11	12	13
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It may be of passing interest to remark that the above is also the calendar for the years 1806, 1817, 1823, 1834, 1845, 1851, 1862, 1873, 1879, 1890, 1902, 1913, 1930, 1941, 1947, 1953, 1969, 1975, 1986, 1997. For times of sunset and sunrise, see 52.522.

CALENDAR FOR 1920.

JANUARY							FEBRUARY							MARCH						
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
...	...	...	...	1	2	3	1	2	3	4	5	6	7	.	1	2	3	4	5	6
4	5	6	7	8	9	10	8	9	10	11	12	13	14	7	8	9	10	11	12	13
11	12	13	14	15	16	17	15	16	17	18	19	20	21	14	15	16	17	18	19	20
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APRIL							MAY							JUNE						
...	...	...	...	1	2	3	...	...	...	...	...	1	...	...	1	2	3	4	5	6
4	5	6	7	8	9	10	2	3	4	5	6	7	8	6	7	8	9	10	11	12
11	12	13	14	15	16	17	9	10	11	12	13	14	15	13	14	15	16	17	18	19
18	19	20	21	22	23	24	16	17	18	19	20	21	22	20	21	22	23	24	25	26
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...	...	...	...	...	...	...	30	31	...	...	...	...	...	...	...	...	...	...	...	...
JULY							AUGUST							SEPTEMBER						
...	...	...	...	1	2	3	1	2	3	4	5	6	7	...	...	1	2	3	4	5
4	5	6	7	8	9	10	8	9	10	11	12	13	14	5	6	7	8	9	10	11
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OCTOBER							NOVEMBER							DECEMBER						
...	...	...	...	1	2	...	...	1	2	3	4	5	6	...	...	1	2	3	4	...
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Also the calendar for the years 1824, 1852, 1880, 1948 and 1976.

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FOREWORD

THIS book is obviously not intended to be read through consecutively from cover to cover. It is essentially a work of reference, covering what is now a considerably wide area of information. A few notes on the general contents, as conceived in the mind of the Author, may therefore economise time in perusal, and facilitate reference.

GENERAL CONTENTS

The Division on Air Pressure and Resistance, bearing the decimal number 533·6·01, and the earlier part of the Division on Airscrews (533·66) are of more theoretical interest, as they deal with the underlying principles of the Art, the subject in each case being followed out in logical sequence, as is indicated by the Division headings. Divisions numbered 533·65 (Aeroplane Design), 674 (Timber), 669 (Metals), 621·434 (Engines), cover the practical data needed by designers, and those who have to come into contact with actual machines in the course of their daily work. Some of the principal information required by the aviator or would-be pilot is dealt with in Divisions numbered 629·13·52·2·002 (Aeroplane Alignment and Rigging), 621·431 (the Care and Maintenance of Engines), 629·13·52·2·0042 (Piloting), 629·13·35·835 (Scouting), and 629·13·018 (Signalling). The Division numbered 629·13(062) is of the nature of a directory, while Division 629·13: 016 provides a key to the latest literature on aviation, and Division 025·4: 629·13 treats of the filing of aeronautical data. A glossary is given in Division 629·13(038), and this was one of the first and most complete to be published. It has been considerably expanded in recent editions of this book, and brought into accord with the latest authorities. It will be found of real

FOREWORD

assistance not only to beginners, but also to others in the settling of doubtful nomenclature.

Conversion tables (531·9) are incorporated at the beginning of the book. Those selected have a special bearing on aviation work. Some general conversion constants, together with logarithms and slide rule constants, have also been included, to serve as a stand-by when complete tables are not available.

Just prior to the index a few sheets of squared paper have been inserted, which it is trusted may prove useful. A calendar will be found immediately following the preface. Postal information and calendar notes find a place on the back of the title page.

NEW FEATURES

A drastic rearrangement of the Divisions, on the International Decimal Classification System, has been made to facilitate reference, and a considerable amount of new matter has been incorporated. In fact, the book has largely been re-written. Further, the DE-tachable DA-ta System of producing the book has been adopted, which should meet a long-felt want. (A special description of this system follows these notes on new features.) Among the newer items, attention may be drawn to the tables of A.G.S. parts in Divisions 621·881 and 629·13·0146, also to notes on parachutes (629·13·6)—a subject of rapidly increasing importance, concerning which very little is generally known at present.

Some new suggestions are included in regard to the rigging of an aeroplane in Division 629·13·52·2·002. Some very interesting data has been added to the Meteorological section (551·591), with a view to making it more practicable.

The glossary has been again revised. This year each term is translated into French, which it is hoped will prove a convenience to many. This glossary would have been even further improved, but for the fact that the latest official Technical Terms of the Royal Aeronautical Society will be available by the time this book is published.

The notes on the classification and the filing of

THE DE-DA SYSTEM

aeronautical data, '025·4:629·13, may prove suggestive to those who find that their collection of data is fast increasing and getting out of hand.

To sum up, it may be stated that, based on past experience, an entirely new and unique work has resulted, which it is anticipated should prove even more informative and of more assistance to its readers than has been the case with previous editions.

It will be appreciated that the novel method of book production, of which this work is the first example, required considerable enterprise on the part of the publishers, so that if the scheme is approved by the readers, the publishers would be glad to hear from them to that effect, as it will encourage them in their efforts.

THE DE-DA (DETACHABLE DATA) SYSTEM

(R. Borlase Matthews' Prov. Patents. American Patents applied for)

From time immemorial engineers have found publications variously described as "pocket-books," "hand-books," or "vade mecum," to be indispensable. The general character of these books presupposes a knowledge of the text-books of the industry, and their function consists in collating tabular matter and the gist of the important principles set out in the text-books; the idea being that the engineer in his everyday work has available, in a very accessible manner, the main points of the information that he most frequently requires for prompt reference.

A very great difficulty that is encountered is that, owing to the rapid expansion of human knowledge on engineering matters, these so-called pocket-books eventually become too bulky for the pocket. Further, they very rapidly get out of date. The only way in which the latter difficulty can be got over is by frequent editions at considerable expense. In increasing the bulk of these reference books they are apt to defeat their own ends, in that they ultimately contain far more information than the user requires. Arising out of these considerations, it would be appreciated that the ideal system would be on the

FOREWORD

loose leaf principle. Normally, there are many mechanical difficulties, and incidentally a high cost in preparing a publication on this system. The solution suggested is, that the advantages of both the ordinary bound pocket-book and the loose leaf system be combined, and, at the same time, provision be made for incorporation of any detachable data in a card index if preferred to a loose leaf book.

This present book is a solution of the problem, for while serving (a) the ordinary purposes of a "pocket-book," it has all the right-hand pages printed with wide inner margins and certain marks which facilitate (b) the cutting of the leaves for insertion in a 6 in. x 4 in. card index (one of the three standard sizes for card indexes); or alternatively (c) the punching of the leaves for insertion of the pages in any standard loose leaf note-book of crown octavo, which is 8 in. x 5 in. (no trimming required); 7 in. x 4½ in. (trim along the outer printed lines); or 4 in. x 6 in. sizes (trim along the inner printed lines); if preferred, the detached leaves may be (d) placed (without any trimming) in an 8 in. x 5 in. standard card index.

An important feature of the scheme is the adoption of the International Decimal System of Classification (described in detail elsewhere). When leaves are detached from the bound book, they should be inserted in the loose leaf book in the correct numerical order of the decimal number at the top right-hand corner of the pages. Then an index will not have to be specially prepared for the loose leaf book, for the International Decimal Classification Index (or an abstract thereof) will serve that purpose. Thus the loose leaf books become automatically self-indexing, so removing the bugbear associated with ordinary home-made note-books.

For those who would like a practical suggestion as to the best way to file the detached data, out of the several mentioned above, a note is given on the next page.

FILING

LOOSE LEAF BOOKS AND FILES

Loose leaf systems are now so well established and popular, that detailed reference is hardly necessary as to their multifarious advantages. A few notes, however, may be of interest to assist in making a selection among the various types now on the market.

Practically speaking, these systems may be divided into two classes, (a) those with the loose leaves attached to rings or hoops which form a part of the back binding of the book, and (b) those where the inner edge of the page is gripped. In either form, the feature of great importance is the maximum facility for removing and replacing the leaves. In most instances the ring type best fulfils these requirements, though there are a few exceptions in the gripping type. For the ring type, the paper used should be comparatively tough, or else strengthened at the punched holes, as considerable strain is brought constantly on the edges of the holes punched in the paper, whereas in the gripping type the holes are only employed for the location of the sheets, since the latter are really held in position by the grip of the stubs of the cover. The ring type book has an advantage in that the whole of the sheet can be employed for notes, etc., whereas a margin of about $\frac{3}{4}$ in. is absorbed by the gripping arrangement in the other type.

A large majority of loose leaf covers have heretofore been supplied solely for the purpose of containing blank sheets of paper and ruled forms, so that if the insertion of other sheets of paper is contemplated, the mechanical principles of the binder should be considered from the point of view of the ease in preparing such special leaves; not the least important requirement being that the punching should be of simple character. In this connection consideration should be given to the types of perforating punches that are easily available. (Refer to the next page for notes on punching.)

A Concrete Suggestion for Filing

One can spend a good deal of money on loose leaf books and files before arriving, by experience, at the final conclusion as to which is the most practicable form for one's own particular purpose. The DE-tachable DA-ta System, which has been adopted in the present book, is purposely designed so as to be as universal in application as possible, and hence it may somewhat confuse anyone who has not studied all systems. If the reader of this book desires to adopt this system he should purchase (1) a loose leaf note-book, including, if possible, some index guides, a perpetual calendar, and also some sheets of paper suitable for general notes and sketches. (2) A standard twin punch, with 70 mm. centres, at about 2s. to 5s., from any stationers. (3) A pair of long-bladed scissors completes the outfit, until the day when an investment is made in a Merrett or similar print trimmer.

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A very convenient way for detaching the leaves from the book, is by drawing an ordinary pin point along the dotted line near the inner side of the right-hand page; preferably using a ruler as a guide. After such scratching with the pin in this way, it will be found that the page is very easily detached. It is not worth while trimming off the very slight roughness caused by the tear, as this edge will always be concealed by the binding cover. The holes indicated by the circles on the right-hand pages of the book are then punched by a twin puncher, and a slit made along the line (also printed on the paper) between the dotted detachment line and each circle. The object of this slit is to enable sheets to be put in the binder at any selected place without the removal of other leaves. After punching and slitting, the leaves should be trimmed around the outer printed line, making the size 7 in. $\times$ 4½ in.* (It should be noted that if it is intended to put the detached leaves in a ring type loose leaf cover, the slits should not be cut; however, in the great majority of cases, three holes are usually required in the sheets for the ring type covers, one of which is in the centre of the page, and the others near the top and bottom edges respectively, and thus they do not interfere with the twin punchings, if a change of cover is considered desirable.)

The lines on the left-hand pages are for decorative purposes only, to balance the appearance of the right-hand pages, hence they should not be used for trimming purposes.

Punching.—The standard single punches on the market make holes $\frac{1}{2}$ in., $\frac{3}{8}$ in. and $\frac{1}{4}$ in. diameter respectively. They are made in two forms, the one with a parallel jaw motion, and the other in the form of a pliers. Twin punches are in much more common use, as they are obtainable at almost any stationer's shop. These twin punches make holes 5 mm. in diameter (approximately $\frac{1}{4}$ in.). There are three types of these twin punches:—

- (a) With the centres of the holes 70 mm. ($2\frac{3}{4}$ in.) apart;
- (b) 80 mm. ($3\frac{1}{4}$ in.) apart; and
- (c) A combination punch which, by moving a lever, cuts holes at either 70 or 80 mm. apart as required.

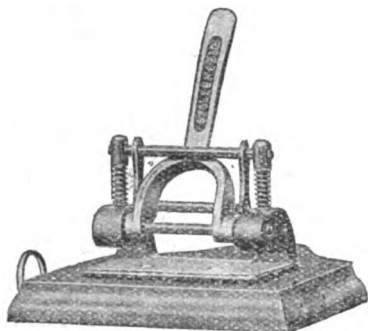
The centres of these holes are punched 10 mm. from the back edge of the paper, which permits of the use of even comparatively weak papers. The majority of grip binders are made for use with these twin punches. The better class twin punches are made with a gauge so as to ensure that the holes are punched at a definite distance from the side edge of the paper.

Somewhat elaborate machines are available, with adjustable dies,

* Marks are printed on the right-hand margin of each page to serve as index tabs; all but one of these tabs should be cut off when it is desired to employ the tab index system. Any desired indexing can then be inserted on this remaining tab. Of course, tabs in varying positions are retained for consecutive pages, so that adjacent tabs do not overlap. Any tabs retained for use should be strengthened by a backing of gummed linen tape.

A CONCRETE SUGGESTION FOR FILING

which can be arranged to suit any standard punching. In selecting any form of paper punch, it is always advisable to choose one in which the cutter enters right into the die, as those which cut on to an anvil on the face of the jaw are not very satisfactory. Single hollow punches, obtainable from tool makers, are also in use, but when employed for cutting paper, are difficult to keep in good cutting order, as paper is notoriously a substance which soon takes the edge off tools. The advantage of these punches is that they can be employed for considerable thicknesses of paper at a time, as they can be driven through the paper with the aid of a hammer. The cutting should always be done by these punches with a lead block underneath the paper, as otherwise the edge of the tool will be blunted, or the last sheets will not be cut properly.



A Twin Punch (Stolzenberg type).

The pages of the Technical Data Handbooks are so prepared that they are adaptable for practically any system of loose leaf binders, whether the ring type or the grip type. The indications printed on each page are intended chiefly for the standard twin punches; however, if a gauge is made of Bristol board or other suitable thin cardboard, with holes in it, corresponding both to the twin punch holes as printed on each page and the holes of the loose leaf book in which it is intended to place the leaves, it will be an easy matter to set this gauge on the unpunched pages by the aid of the printed marks, and then punch through the positions indicated as required for the special binder. Alternatively, if the leaves are first carefully trimmed to the correct size, and a special twin or multiple punch be employed, the punching can be done at the required definite distance from the top edge of each page.

Trimming.—In order to ensure that the edges of the leaves shall lie as evenly as possible compared with one another, when placed in their binders, it is advisable to trim each leaf on its top, bottom

and outside edges. This can be done, if care is exercised, by the aid of a scissors; preferably with long blades, not less than $4\frac{1}{2}$ in. from the hinge, and preferably 6 in. or even over, that is to say, a proper paper-cutting scissors. The best plan, however, is to employ what is known as a print trimmer, sold for trimming photographic prints. These trimmers consist of a board with a scale mounted thereon, and a guillotine knife; an excellent type is that known as the "Merrett." In this pattern, the cutting board proper is hinged, and normally stands at an angle to its base. The sheet of paper to be cut is placed on this board, with the edge to be trimmed off, extending outside it, and the whole pressed down against the pressure of a spring, and in so doing it meets a sloped knife blade at the back edge, which cuts off the protruding edge of the paper. The chief advantage of this apparatus is that both hands are free to hold the paper, and it is easier to guide it and at the same time watch the cutting. In cases where punching and trimming are often required to be done, it is a good plan to insert four nails, having heads the same diameter as the punch holes, in the cutting board, almost flush with the surface (so as not to interfere with ordinary trimming work). Two of these nail heads will then serve as gauge points for cutting the top and bottom edges of the leaves, and the other two placed horizontally for trimming the outside edge of each leaf. In this way, every leaf is bound to be trimmed in definite relation to the punch holes.

CLASSIFICATION

.025.4 : 629.13

Those who are engaged in aeronautical engineering, as well as in many other occupations, cannot but accumulate in course of time a very large and varied collection of technical data, general information, reports, drawings, books, etc., and without some effective system of indexing it is obvious that such becomes but a mass of detail from which it is practically impossible to extricate exactly what is required from time to time, quickly and easily. Older methods of filing, mostly dependent upon an alphabetical arrangement, are inadequate to cope with the difficulty, as either only the very general heads of the filed matter are dealt with, or else the index is in itself so extensive and complicated as to hamper the prompt location of the subject desired.

The contents of this book have been arranged according to the order and classification of human knowledge, which was published by the Institut International de Bibliographie at Brussels in 1905.*

This classification was chosen chiefly on account of its universal use, great simplicity and uniformity, and on account of the important property of the decimal numbers, i.e., that they are capable of being placed in a rigorously determined order, and that new numbers may be indefinitely introduced between any

* "Manuel du Repertoire Bibliographique Universel," Bruxelles.

existing two without interfering with the previously determined classification.

In order to provide for the expansion of knowledge, and especially for the rapidly developing field of aeronautics, this is an essential property of a system of bibliographical classification. Though the system of decimal classification was originally devised and applied by Melvil Dewey as long ago as 1873 in America to the library classification of books, and was later vastly extended and improved by the Institut International de Bibliographie for application to all kinds of classifiable matter, it is better known in America and on the Continent than perhaps in Britain.

A short description of the system may therefore render the arrangement of this book a little more intelligible to those to whom the Decimal Classification is new.

In order to establish the series of classification numbers adopted, it may be supposed that the whole of human knowledge is represented by unity, divided into ten decimal classes, in which should appear all the subjects of intellectual activity. Each of these classes is divided into nine divisions, and each division into nine subdivisions. This process may then be continued until the main classes are sifted down to the smallest detail of an intellectual work.

The main classes which have been established are as follows :—

- 0·0 General works and bibliography.
- 0·1 Philosophy.
- 0·2 Religion.
- 0·3 Sociology. Law.
- 0·4 Philology.
- 0·5 Pure science.
- 0·6 Applied science. Industry.
- 0·7 Fine arts.
- 0·8 Literature.
- 0·9 History, geography.

Each one of these is further divided and subdivided to whatever extent is necessary, and as an example, one detail of 0·5 Pure Science may be taken :—Magnetic Compasses.

0·5 is divided in its turn, as explained above, into divisions comprising mathematics, astronomy, physics, chemistry, etc., and there results :—

- 5 Pure science.
- 53 Physics.
- 538 Magnetism and Electromagnetism.
- 5387 Terrestrial magnetism.
- 53874 Compasses. Regulation. Compensation.

The subdivisions of compasses could be carried further still, by addition of another number to the right of the last decimal, and these subdivisions could be interpolated between the divisions

previously established, without interference of the original classification.

The necessity of this property to a loose-leaf book or a card index is self-evident.

In the practical application of these decimal numbers, the decimal point is omitted as unnecessary, and the decimal figures are divided into groups of two or three figures by full stops or commas to emphasise the subdivisions, and to aid the eye and mind ; the above example will then be written :—

538·74

The ten figures are employed for the classification numbers without distinction and in the same manner, except that sometimes the zero gives rise to some special rules. The zero which appears at the head of the ten classes indicates **general works**, but the intercalated zero is reserved as a sign of combination, and by means of it a series of numbers are formed, which comprise special tables. One group of these special tables, known as **analytical subdivisions**, may be applied to any decimal number throughout the classification, and are formed by a double zero. Another group, known as **special analytical subdivisions**, formed by a single zero, are applicable only to specified divisions in the classification.

The principal divisions of the first group are as follows :—

- ...00·1 **Speculative**.—Conception. Researches and theoretical studies, etc.
- ...00·2 **Realisation**.—Execution. Construction, etc.
- ...00·3 **Economic**.—Industrial production. Selling price.
- ...00·4 **Service and employment**.—Working, etc.
- ...00·5 **Furnishing and equipment**.
- ...00·6 **Localities and establishments**. — Details of organisation and service.
- ...00·7 **Special personnel**.

These numbers express a **point of view**, and as an example...00·1 applied to the chosen number would be written 538·74·001, and would imply a theoretical study or research upon magnetic compasses, whilst 538·74·004 would be the decimal designation upon a pamphlet explaining the use of the magnetic compass. Another group of numbers are formed by a single zero within brackets, the principal divisions of which are :—

- (01) Theory of the subject.
- (02) Manual, treatise, precis of...
- (03) Encyclopedia, dictionary of...
- (04) Conference, thesis, discourse, essay on...
- (05) Periodical, review of...
- (06) Societies, institutions, congresses, exhibitions of...
- (07) Teaching and study of...
- (08) Collection, polygraphs of...
- (09) Historical works on...History of...

These numbers can also be applied to any number throughout the classification and express the notion of **form**. Thus:—

538-74 (02) A treatise on the compass.

538-74 (09) History of the compass.

Other subdivisions which are common to the whole classification comprise (a) **geographical**, indicated by an integer between brackets as (42) English; (b) **Linguistic**, indicated by the sign =, thus an Italian work on botany would be 58=5; (c) **Chronological**, in which the year written between inverted commas is attached to the decimal number, thus 9 (44) "1467," History of France in 1467.

The universal application of the system of the decimal classification to any human notion is made possible by the use of three signs, the most important of which is that of **relation** expressed by a colon:

Thus, **salaries** is represented by 331-2. **The textile industry** by 677, so that the compound notion of salaries in the textile industry would be represented by

331-2 : 677

i.e., seven figures and a sign to represent a phrase of five words or twenty-eight letters, and here it should be noted that the decimal number is independent of language, and denotes a notion of the mind which may be expressed in many different ways in any one language and in different languages.

The above example may be written 677 : 331-2 in duplicate, so that if the information was sought for either in "salaries" or "textile industries" it would be found.

The order in which these numbers follow one another in a card index, for example, is the decimal order, but the special signs described above follow in the following order:—

(), " ", =, :, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9.

Thus, for example, the series of pages bearing the following numbers would be filed in the following order:—

621-13.	621-13 : 622.
621-13 (02).	621-13-0011.
621-13 (44).	621-13-11.
621-13 (5).	621-13-24.
621-13 "1918."	621-13-484.

It is unnecessary to enter into any further explanation of the decimal classification, but it should be borne in mind that the complete system as developed in the "Manuel du Répertoire Bibliographique Universel" enables any notion or combination of notions whatsoever to be written down as a decimal number occupying a rigorously fixed position in the entirety of the number complex of the classification.

The value of this classification as a powerful tool of bibliographical research, as a precise and simple method for the ordering of notes, data, information upon general themes, or upon the smallest detail, it is hardly necessary to mention, but it should be borne in mind that the classification is a bibliographical and not a philosophical attempt to group the notions of the intellect, so that information once classified and put away may be found again with the least waste of time and the least mental effort.

THE PRIMARY DIVISIONS AND SUBDIVISIONS OF THE DECIMAL CLASSIFICATION*

- | | |
|------------------------------------|--|
| 0 General Works. | 3 Sociology. Law. |
| 01 Bibliography. | 31 Statistics. |
| 02 Library economy. | 32 Political science. |
| 03 General encyclopedias. | 33 Political economy. |
| 04 General collections and essays. | 34 Law. |
| 05 General periodicals. | 35 Administration. |
| 06 General societies. | 36 Charities. Insurance. Associations. |
| 07 Newspapers. Journalism. | 37 Education. |
| 08 Polygraphy. Special libraries. | 38 Commerce. Communication. |
| 09 Manuscripts. Book rarities. | 39 Customs. Costumes. Folklore. |
| 1 Philosophy. | 4 Philology. |
| 11 Metaphysics. | 41 Comparative philology. |
| 13 Mind and body. | 42 English philology. |
| 14 Philosophical systems. | 43 German philology. |
| 15 Psychology. | 44 French philology. |
| 16 Logic. | 45 Italian philology. |
| 17 Ethics. | 46 Spanish philology. |
| 18 Ancient philosophers. | 47 Latin philology. |
| 19 Modern philosophers. | 48 Greek philology. |
| 2 Religion. Theology. | 49 Other languages. |
| 21 Natural theology. | 5 Pure Science. |
| 22 Bible. | 51 Mathematics. |
| 23 Doctrinal, dogmatic theology. | 52 Astronomy. Geodesy. Navigation. |
| 24 Devotional. Practical. | 53 Physics. |
| 25 Homiletic. Pastoral, parochial. | 54 Chemistry. Mineralogy. |
| 26 Church. | 55 Geology. |
| 27 Religious history. | 56 Paleontology. |
| 28 Christian churches and sects. | 57 Biology. Anthropology. |
| 29 Non-Christian religions. | 58 Botany. |
| | 59 Zoology. |

* See footnote at the end of this skeleton classification.

- | | |
|---|--|
| <p>6 Applied Science. Technology.
 61 Medicine.
 62 Engineering.
 63 Agriculture.
 64 Domestic economy.
 65 Communication. Commerce.
 66 Chemical technology.
 67 Manufactures.
 68 Mechanic trades.
 69 Building.</p> <p>7 Fine Arts.
 71 Landscape gardening.
 72 Architecture.
 73 Sculpture.
 74 Drawing. Decoration.
 75 Painting.
 76 Engraving.
 77 Photography.
 78 Music.
 79 Amusements. Games.</p> | <p>8 Literature.
 82 English.
 83 German.
 84 French.
 85 Italian.
 86 Spanish.
 87 Latin.
 88 Greek.
 89 Other literature.</p> <p>9 History and Geography.
 9(3) Ancient history.
 9(4) European history.
 9(5) Asiatic history.
 9(6) African history.
 9(7) North American history.
 9(8) South American history.
 9(9) History of Oceania and the Polar regions.
 91 Geography and travels.
 92 Biography.</p> |
|---|--|

The foregoing is, of course, but a skeleton of the complete classification, given so as to make the method clear to those who have not previously studied it. The general classified arrangement of this book is an illustration of the application of the classification, and the list of contents forms a summary. The original classification was intended chiefly for books, but in later years its great advantages for the filing of technical data and notes has been more and more appreciated. Jointly with Captain A. F. C. Pollard, the author has prepared a special extension for the purpose of filing Aeronautical and Similar Technical Data.*

GENERAL NOTES ON FILING

The ideal mechanical method of filing a main collection of technical or, in fact, any data, is in tabbed, stout manila paper folders in a vertical file, preferably in a vertical filing cabinet. A separate card index, as a guide to the folders, is too troublesome and out-of-date a method to adopt. Hence it is advisable to employ the more modern system of decimal classification which has just been set forth. This method has the very great advantage in that it offers a ready prepared index. So all that has to be done is to number each new folder as it is filed away. There is then no need for delay in filing, no index cards to make out, no holes to punch, no pasting—in short, the minimum of trouble—which alone does much to ensure the

* See Bibliography at the end of the next page.

prompt filing of data. Further, any required data is as easy to find as it is to file.

It is a good scheme to insert a stout piece of millboard (the same size as the folders) between about every dozen folders or so, so as to stiffen them up, and prevent the drawer becoming untidy. These stout boards should be tabbed, so as to serve as guides. Preferably the tabs should be covered with celluloid, as then they keep clean and clear.

It is very necessary to date all cuttings, for a date is of the utmost importance in aeronautical work in its present rapidly-changing phase. An effective method of quickly taking a cutting from a journal or paper is to scratch round it with an ordinary pin point, when it will be found to detach itself quite easily. When practicable, two copies of each journal, from which it is desired to take cuttings, should be obtained. In one number a blue pencil line should be scored down the centre of the columns on the right-hand pages, and a similar scoring applied to the left-hand pages of the other number. In this way the equivalent of an edition printed on one side of the page is obtained, and that annoying clashing of the parts of two different articles on the same cutting is obviated. The object of the marking is to save the confusion that often arises in preparing clippings, as to which is the required side of the piece.

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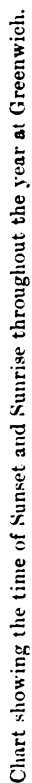
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— 1 —
Chas. L. K. & Co. Son's TECHNICAL DATA SERIES

THE AVIATION POCKET-BOOK



FEEDA (Feed-Enhance Data) System
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THE SUN AND MOON

THE chart on the other side of this page gives a diagrammatic representation of the time of sunset and sunrise at Greenwich. The shaded area between the curved lines indicates the portions of each day during the year throughout which darkness prevails. One hour after sunset and one hour before sunrise are indicated by the ends of the short, shading lines. The sun rises at points which vary between N.E. and S.E., according to the season of the year, and sets likewise between N.W. and S.W.

Sunset.—For each degree of longitude west of Greenwich add 4 minutes; for each degree east deduct 4 minutes. In addition to this constant figure there is a variation depending upon the period of the year for places north or south of Greenwich, thus:—

March, September	- - -	A slight difference only.
April, October	- - -	About 2 minutes a degree.
May, November	- - -	" 4 " "
June, December	- - -	" 5 " "
July, January	- - -	" 4 " "
August, February	- - -	" 3 " "

From March to August the minutes given are to be added, and from September to February subtracted for places north of Greenwich, and vice versa for places south of Greenwich.

Hours of Moonlight

When the moon is 4 days old, it shines till about 10 P.M.	
" " 5 " " "	11 "
" " 6 " " "	12 "
" " 7 " " "	1 A.M.
" " 15 days old, full moon rises about 6 P.M.	
" " 16 " " "	7 "
" " 17 " " "	8 "
" " 18 " " "	10 "
" " 19 " " "	11 "
" " 20 " " "	12 "

Phases of the Moon

The appearances of the moon are by custom restricted to the particular phases of *new moon*, [●], when nothing is visible; *first quarter*, or waxing moon, [☾], when a semicircle is visible, with the bow on the west; *full moon*, [☉], when a full circle is visible; and *last quarter*, or waning moon, [☾], when a semicircle is visible, with the bow on the east. A waxing moon has the circular edge on the right: horns to the left. A waning moon has the circular edge on the left: horns to the right (i.e., opposite way to **O**rescent and **D**ecrescent).

THE AVIATION POCKET-BOOK

52.522

TABLE OF AVERAGE TIME OF SUNRISE AND SUNSET
AT GREENWICH

Day of Month.	January.		February.		March.		April.	
	Rise.	Set.	Rise.	Set.	Rise.	Set.	Rise.	Set.
1	8·8	3·59	7·41	4·47	6·47	5·38	5·37	6·30
2	8·8	4·0	7·39	4·49	6·45	5·39	5·35	6·32
3	8·8	4·1	7·38	4·51	6·43	5·41	5·33	6·34
4	8·8	4·3	7·36	4·52	6·41	5·43	5·30	6·35
5	8·8	4·4	7·34	4·54	6·39	5·45	5·28	6·37
6	8·7	4·5	7·33	4·56	6·36	5·47	5·26	6·39
7	8·7	4·6	7·31	4·58	6·34	5·48	5·24	6·41
8	8·6	4·7	7·29	5·0	6·31	5·50	5·22	6·42
9	8·6	4·9	7·27	5·2	6·30	5·52	5·19	6·44
10	8·5	4·10	7·26	5·3	6·27	5·54	5·17	6·45
11	8·5	4·11	7·24	5·5	6·25	5·55	5·16	6·47
12	8·4	4·13	7·22	5·7	6·23	5·57	5·13	6·49
13	8·3	4·14	7·20	5·9	6·21	5·59	5·10	6·50
14	8·2	4·16	7·18	5·11	6·18	6·0	5·8	6·52
15	8·2	4·18	7·16	5·13	6·16	6·2	5·6	6·54
16	8·1	4·19	7·13	5·14	6·14	6·4	5·4	6·55
17	8·0	4·21	7·12	5·16	6·12	6·5	5·2	6·57
18	7·59	4·22	7·10	5·18	6·9	6·7	5·0	6·59
19	7·58	4·24	7·8	5·20	6·7	6·9	4·59	7·0
20	7·57	4·25	7·6	5·22	6·5	6·10	4·55	7·2
21	7·56	4·27	7·4	5·23	6·2	6·12	4·53	7·4
22	7·54	4·29	7·2	5·25	6·0	6·14	4·51	7·5
23	7·53	4·31	7·0	5·27	5·57	6·16	4·49	7·7
24	7·52	4·33	6·58	5·29	5·56	6·17	4·47	7·9
25	7·51	4·34	6·56	5·31	5·53	6·19	4·45	7·10
26	7·49	4·36	6·54	5·32	5·51	6·21	4·43	7·12
27	7·48	4·38	6·51	5·34	5·49	6·22	4·41	7·14
28	7·47	4·40	6·49	5·36	5·46	6·24	4·39	7·15
29	7·45	4·41	6·48	5·37	5·44	6·26	4·37	7·17
30	7·44	4·43	...	...	5·42	6·27	4·36	7·19
31	7·42	4·45	...	...	5·40	6·29	...	...

For English Summer Time add one hour.

SUNRISE AND SUNSET

52.522

TABLE OF AVERAGE TIME OF SUNRISE AND SUNSET
AT GREENWICH—*Continued*

Day of Month.	May.		June.		July.		August.	
	Rise.	Set.	Rise.	Set.	Rise.	Set.	Rise.	Set.
1	4:34	7:20	3:50	8:5	3:49	8:18	4:25	7:47
2	4:32	7:22	3:50	8:6	3:50	8:18	4:27	7:45
3	4:30	7:23	3:49	8:7	3:50	8:17	4:28	7:44
4	4:28	7:25	3:48	8:8	3:51	8:17	4:30	7:42
5	4:26	7:27	3:48	8:9	3:52	8:16	4:31	7:40
6	4:25	7:28	3:47	8:10	3:53	8:16	4:33	7:38
7	4:23	7:30	3:46	8:10	3:54	8:15	4:35	7:37
8	4:21	7:31	3:46	8:11	3:55	8:15	4:36	7:35
9	4:19	7:33	3:46	8:12	3:56	8:14	4:38	7:33
10	4:18	7:35	3:45	8:13	3:57	8:13	4:39	7:31
11	4:16	7:36	3:45	8:14	3:58	8:13	4:41	7:29
12	4:15	7:38	3:45	8:14	3:59	8:12	4:42	7:27
13	4:13	7:39	3:44	8:15	4:01	8:11	4:44	7:25
14	4:11	7:40	3:44	8:16	4:1	8:10	4:45	7:23
15	4:10	7:42	3:44	8:16	4:2	8:9	4:47	7:21
16	4:8	7:44	3:44	8:17	4:3	8:8	4:49	7:19
17	4:7	7:45	3:44	8:17	4:4	8:7	4:50	7:17
18	4:6	7:47	3:44	8:17	4:6	8:6	4:52	7:16
19	4:4	7:48	3:44	8:18	4:7	8:5	4:53	7:14
20	4:3	7:49	3:44	8:18	4:8	8:4	4:55	7:12
21	4:2	7:51	3:44	8:18	4:10	8:2	4:57	7:9
22	4:1	7:52	3:45	8:18	4:11	8:1	4:58	7:7
23	3:59	7:54	3:45	8:19	4:12	8:0	5:0	7:5
24	3:58	7:55	3:45	8:19	4:14	7:59	5:1	7:3
25	3:57	7:56	3:46	8:19	4:15	7:57	5:3	7:1
26	3:56	7:57	3:46	8:19	4:16	7:56	5:5	6:59
27	3:55	7:59	3:47	8:19	4:18	7:54	5:6	6:57
28	3:54	8:0	3:47	8:19	4:19	7:53	5:8	6:54
29	3:53	8:1	3:48	8:19	4:21	7:52	5:9	6:52
30	3:52	8:2	3:48	8:18	4:22	7:50	5:11	6:50
31	3:51	8:3	...	...	4:24	7:48	5:12	6:48

For English Summer Time add one hour.

THE AVIATION POCKET-BOOK

52.522

TABLE OF AVERAGE TIME OF SUNRISE AND SUNSET
AT GREENWICH—Continued

Day of Month.	September.		October.		November.		December.	
	Rise.	Set.	Rise.	Set.	Rise.	Set.	Rise.	Set.
1	5.14	6.46	6.2	5.37	6.56	4.32	7.46	3.53
2	5.16	6.43	6.4	5.35	6.57	4.30	7.47	3.52
3	5.17	6.41	6.6	5.33	6.59	4.28	7.49	3.51
4	5.19	6.39	6.7	5.30	7.1	4.26	7.50	3.51
5	5.20	6.37	6.9	5.28	7.3	4.25	7.51	3.50
6	5.22	6.34	6.11	5.26	7.5	4.23	7.52	3.50
7	5.24	6.32	6.12	5.23	7.6	4.21	7.54	3.50
8	5.25	6.30	6.14	5.21	7.8	4.20	7.55	3.49
9	5.27	6.28	6.16	5.19	7.10	4.18	7.56	3.49
10	5.28	6.25	6.17	5.17	7.12	4.16	7.57	3.49
11	5.30	6.23	6.19	5.15	7.13	4.15	7.58	3.49
12	5.32	6.21	6.21	5.12	7.15	4.13	7.59	3.49
13	5.33	6.18	6.22	5.10	7.17	4.12	8.0	3.49
14	5.35	6.16	6.24	5.8	7.19	4.11	8.1	3.49
15	5.36	6.14	6.26	5.6	7.20	4.9	8.2	3.49
16	5.38	6.12	6.27	5.4	7.22	4.8	8.3	3.49
17	5.40	6.9	6.29	5.2	7.24	4.6	8.4	3.49
18	5.41	6.7	6.31	5.0	7.25	4.5	8.4	3.49
19	5.43	6.5	6.33	4.57	7.27	4.4	8.4	3.50
20	5.44	6.2	6.34	4.55	7.29	4.3	8.5	3.51
21	5.46	6.0	6.36	4.53	7.30	4.2	8.5	3.51
22	5.48	5.58	6.38	4.51	7.32	4.0	8.6	3.52
23	5.49	5.55	6.40	4.49	7.34	3.59	8.6	3.52
24	5.51	5.53	6.41	4.47	7.35	3.58	8.7	3.52
25	5.53	5.51	6.43	4.45	7.37	3.57	8.7	3.53
26	5.54	5.48	6.45	4.43	7.39	3.56	8.7	3.53
27	5.56	5.46	6.47	4.41	7.40	3.55	8.7	3.54
28	5.57	5.44	6.49	4.39	7.42	3.55	8.7	3.55
29	5.59	5.42	6.50	4.37	7.43	3.54	8.8	3.56
30	6.1	5.39	6.52	4.35	7.44	3.53	8.8	3.57
31	...	...	6.54	4.34	...	...	8.8	3.58

For English Summer Time add one hour.

CONVERSION TABLES

CERTAIN metric tables are here included, as they are used for such constant reference in aeroplane work. Multipliers, logarithms and slide rule gauge points have been incorporated in a very compact form, to serve as a standby when complete conversion tables are not available.

For standard screw threads and tables of limits, reference should be made to division 621.881.

To ascertain the weight of a body by the metric system, multiply its volume in cubic centimetres by its specific gravity; this gives the weight in grammes. Move the decimal point three places to the left for kilogrammes, or six places to the left for metric tons.

With reference to the Table of Multipliers and Slide Rule Conversions, the item in the column headed "Known Quantity," when multiplied by the number set down in the second column as the "Multiplier," gives the denomination in the third column — the "Required Quantity." Therefore a unit of the "Known Quantity" is represented by the "Multiplier" times the number of units of the "Required Quantity." *E.g.*, on reference to the above table it will be seen that "British Thermal Units $\times 0.252$ = Great Calories," hence one British Thermal Unit = 0.252 Great Calorie. The reciprocal of 0.252 (i.e., $1 \div 0.252$) = 3.968 . This, of course, is the number of British Thermal Units in a Great Calorie. For convenience, the reciprocals of all the conversions are given in the above table. It will be observed that, for use on the slide rule, the gauge points are interchanged, for the reciprocals.

It will be noted that the number on the rule, divided by the number on the slide, gives the multiplier.

A companion volume to this one is in course of preparation, by the present author, which is to include much more complete conversion tables, factors, formulæ and mathematical tables. It is designed as a separate book, on the DE-tachable DA-ta System, and is intended to cover, in an improved manner, the tables of this nature usually incorporated in engineering pocket-books. Messrs Crosby Lockwood & Son expect to publish this work in due course.

CONVERSIONS OF LENGTH

CENTIMETRES AND INCHES.			METRES AND FEET.			METRES AND YARDS.		
In. $\times 2.5399 =$ cm. cm. $\times 0.3937 =$ in.			Ft. $\times 0.3048 =$ m. m. $\times 3.2808 =$ ft.			Yds. $\times 0.9144 =$ m. m. $\times 1.093 =$ yds.		
SLIDE RULE— On Slide (in.), 50. On Rule (cm.), 127.			SLIDE RULE— On Slide (ft.), 292. On Rule (m.), 89.			SLIDE RULE— On Slide (yds.), 35. On Rule (m.), 32.		
Centi- metres.	*	Inches.	Metres.		Feet.	Metres.		Yards.
2.5399	1	0.3937	0.3048	1	3.2808	0.914	1	1.093
5.0799	2	0.79	0.609	2	6.562	1.829	2	2.187
7.6199	3	1.18	0.914	3	9.843	2.743	3	3.281
10.1598	4	1.57	1.219	4	13.124	3.658	4	4.374
12.6998	5	1.97	1.524	5	16.405	4.572	5	5.468
15.2397	6	2.36	1.829	6	19.685	5.486	6	6.562
17.7797	7	2.75	2.133	7	22.966	6.401	7	7.655
20.3196	8	3.15	2.438	8	26.247	7.315	8	8.749
22.8596	9	3.54	2.743	9	29.528	8.229	9	9.843
25.3995	10	3.94	3.048	10	32.809	9.144	10	10.936
38.0993	15	5.90	4.572	15	49.214	13.816	15	16.404
50.7990	20	7.87	6.096	20	65.618	18.288	20	21.873
76.1985	30	11.81	9.144	30	98.427	27.432	30	32.809
101.5980	40	15.75	12.192	40	131.236	36.576	40	43.745
126.9975	50	19.68	15.239	50	164.045	45.719	50	54.682
152.3971	60	23.62	18.287	60	196.854	54.863	60	65.618
177.7966	70	27.56	21.335	70	229.663	64.007	70	76.554
203.1961	80	31.50	24.383	80	262.472	73.151	80	87.491
228.5956	90	35.43	27.431	90	295.281	82.295	90	98.427
253.9951	100	39.37	30.479	100	328.090	91.438	100	109.363

* In order to bring millimetres to inches, shift the point one to the left. In order to bring inches to millimetres, shift the point one to the right, e.g., 8 millimetres = 0.315 inch; 8 inches = 203.196 millimetres.

The figures in the central columns refer to either side; e.g., in the first column the first line means that 1 inch = 2.5399 centimetres, or that 1 centimetre = 0.3937 inch.

CONVERSION TABLES

531.9

CONVERSIONS OF

LENGTH,

VOLUME,

WEIGHT.

KILOMETRES AND MILES.			LITRES AND GALLONS.			KILOGRAMMES AND POUNDS.		
Miles $\times 1.60932 =$ km. km. $\times 0.62138 =$ miles.			Gals. $\times 4.5434 =$ litres. Litres $\times 0.2201 =$ gals.			Lbs. $\times 0.4535 =$ kg. kg. $\times 2.2046 =$ lbs.		
SLIDE RULE— On Slide (miles), 87. On Rule (km.), 140.			SLIDE RULE— On Slide (gals.), 11. On Rule (lit.), 50.			SLIDE RULE— On Slide (lbs.), 280. On Rule (kg.), 127.		
Kilometres.		Miles.	Litres.		Gallons.	Kilog.		Lbs.
1.609	1	0.621	4.543	1	0.220	0.454	1	2.205
3.219	2	1.243	9.087	2	0.440	0.907	2	4.409
4.828	3	1.864	13.630	3	0.660	1.361	3	6.614
6.438	4	2.486	18.174	4	0.880	1.814	4	8.818
8.047	5	3.107	22.717	5	1.110	2.268	5	11.023
9.656	6	3.728	27.261	6	1.321	2.721	6	13.228
11.265	7	4.350	31.804	7	1.541	3.175	7	15.432
12.879	8	4.971	36.348	8	1.761	3.629	8	17.637
14.484	9	5.592	40.891	9	1.981	4.082	9	19.841
16.093	10	6.214	45.435	10	2.201	4.536	10	22.046
24.140	15	9.321	68.152	15	3.311	6.804	15	33.069
32.186	20	12.428	90.869	20	4.402	9.072	20	44.092
48.279	30	18.641	136.304	30	6.603	13.608	30	62.139
64.373	40	24.855	181.738	40	8.804	18.144	40	88.185
80.466	50	31.069	227.173	50	11.105	22.679	50	110.231
96.559	60	37.283	272.607	60	13.206	27.215	60	132.228
112.652	70	43.497	318.042	70	15.407	31.751	70	154.322
128.746	80	49.710	363.477	80	17.608	36.287	80	176.369
144.839	90	55.924	408.911	90	19.809	40.823	90	198.416
160.932	100	62.138	454.346	100	22.010	45.359	100	220.462

CONVERSIONS OF PRESSURE

KILOGRAMMES PER SQUARE METRE AND POUNDS PER SQUARE FOOT.			KILOGRAMMES PER SQUARE CENTIMETRE AND POUNDS PER SQUARE INCH.		
Lbs. per sq. ft. $\times 4.882407$ = kg. per sq. m. kg. per sq. m. $\times 0.20482$ = lbs. per sq. ft.			Lbs. per sq. in. $\times 0.070307$ = kg. per cm. ² kg. per cm. ² $\times 14.22382$ = lbs. per sq. in.		
SLIDE RULE— On Slide (lbs. per sq. ft.), 17. On Rule (kg. per sq. m.), 83.			SLIDE RULE— On Slide (lbs. per sq. in.), 37. On Rule (kg. per cm. ²), 26.		
Kg. per Sq. Metre.		Lbs. per Sq. Ft.	Kg. per Cm. ²		Lbs. per Sq. In.
4.883	1	0.205	0.0703	1	14.223
9.765	2	0.410	0.1406	2	28.447
14.648	3	0.614	0.2109	3	42.670
19.530	4	0.819	0.2812	4	56.893
24.413	5	1.024	0.3515	5	71.117
29.296	6	1.229	0.4218	6	85.340
34.178	7	1.434	0.4921	7	99.563
39.060	8	1.638	0.5624	8	113.787
43.943	9	1.843	0.6327	9	128.010
48.825	10	2.048	0.7031	10	142.233
53.708	11	2.253	0.7733	11	156.456
58.590	12	2.458	0.8437	12	170.680
63.473	13	2.663	0.9140	13	184.903
68.355	14	2.867	0.9843	14	199.126
73.238	15	3.072	1.0546	15	213.350
78.119	16	3.277	1.1249	16	227.573
83.001	17	3.482	1.1952	17	241.796
87.884	18	3.686	1.2655	18	256.020
92.766	19	3.891	1.3358	19	270.243
97.649	20	4.096	1.4061	20	284.466
146.473	30	6.144	2.1092	30	426.699
195.297	40	8.192	2.8123	40	568.933
244.122	50	10.240	3.5154	50	711.166
292.946	60	12.288	4.2184	60	853.399
341.771	70	14.337	4.9215	70	995.632
390.595	80	16.385	5.6246	80	1137.865
439.419	90	18.433	6.3276	90	1280.098
488.240	100	20.482	7.0307	100	1422.382

Alter two places of decimals for each division of the metre, e.g.—
 50 lbs. per sq. ft. = 244.122 kg. per sq. mm. = 2.44122 kg. per sq. dm.
 50 „ „ in. = 3.5153 „ „ cm. = 0.035153 „ mm.
 50 kg. „ mm. = 71116.6 lbs. „ in.
 50 „ „ dm. = 1024.08 „ „ ft.

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 D.E.-D.A. (Detachable Data) System
 R. Barlowe Matheson Patents (functionally protected). U.S. Patents applied for.

CONVERSION TABLES

531.9

CONVERSIONS OF VELOCITIES

MILES PER HOUR AND METRES PER SECOND.			MILES PER HOUR AND FEET PER SECOND.		
Miles per hour $\times 0.447$ = metres per sec. Metres per sec. $\times 2.237$ = miles per hour.			Miles per hour $\times 1.467$ = feet per sec. Feet per sec. $\times 0.6818$ = miles per hour.		
SLIDE RULE— On Slide (miles per hour), 28. On Rule (metres per sec.), 125.			SLIDE RULE— On Slide (miles per hour), 30. On Rule (feet per sec.), 44.		
Miles per Hour.		Metres per Second.	Miles per Hour.		Feet per Second.
2.237	1	0.447	0.6818	1	1.467
4.47	2	0.894	1.36	2	2.9
6.71	3	1.341	2.04	3	4.4
8.95	4	1.788	2.72	4	5.9
11.80	5	2.235	3.41	5	7.3
13.42	6	2.682	4.08	6	8.8
15.66	7	3.129	4.77	7	10.3
17.90	8	3.576	5.44	8	11.7
20.14	9	4.023	6.12	9	13.2
22.37	10	4.47	6.818	10	14.67
24.61	11	4.92	7.49	11	16.1
26.84	12	5.36	8.16	12	17.6
29.08	13	5.81	8.86	13	19.1
31.32	14	6.26	9.54	14	20.5
33.55	15	6.71	10.23	15	22.0
35.97	16	7.15	10.88	16	23.5
38.03	17	7.60	11.59	17	24.9
40.27	18	8.05	12.24	18	26.4
42.51	19	8.49	12.95	19	27.8
44.74	20	8.94	13.63	20	29.3
46.98	21	9.39	14.31	21	30.8
49.21	22	9.83	14.99	22	32.3
51.45	23	10.28	15.67	23	33.7
53.69	24	10.73	16.32	24	35.2
55.92	25	11.17	17.45	25	36.7
58.16	26	11.62	17.72	26	38.1
60.34	27	12.07	18.40	27	39.6
62.64	28	12.52	19.08	28	41.1
64.87	29	12.96	19.76	29	42.5
67.11	30	13.41	20.45	30	44.0
69.48	40	17.88	27.26	40	58.7
111.85	50	22.35	34.91	50	73.3
134.22	60	26.82	40.90	60	88.0
156.59	70	31.29	47.72	70	102.7
198.96	80	35.76	54.52	80	117.3
201.33	90	40.23	61.35	90	132.0
223.70	100	44.70	68.182	100	146.7

MULTIPLIERS AND SLIDE RULE CONVERSIONS

Known Quantity (on Slide).	Multiplier.	Required Quantity (on Rule).	Logarithm.	On Slide.	On Rule.
GEOMETRICAL—					
Circle, diameter -	- x 3.1416	= Circle, circumference	0.497 1499	226	710
Circle, diameter -	...	= Side of equal square	...	79	70
LENGTH—					
Inches -	- x 0.083	= Feet	2.920 8188	12	1
Inches -	- x 0.0277	= Yards	2.443 6975	36	1
Inches -	- x 0.0254	= Metres	2.404 8346	50	1.27
Feet -	- x 0.3048	= Metres	1.484 0146	292	89
Yards -	- x 0.9144	= Metres	1.091 1371	35	32
Miles -	- x 1609.3	= Metres	3.206 6497	.87	1400
Metres -	- x 39.3701	= Inches	1.595 1666	1.27	50
Metres -	- x 3.2808	= Feet	0.515 9842	89	292
Metres -	- x 1.0936	= Yards	0.038 8629	32	35
Metres -	- x 0.0006214	= Miles	4.793 3503	1400	.87
Move decimal point of m. back three places for mm., two places for cm., and one place for dm. Move it forward three places for km.					
AREA—					
Square inches	- x 6.4516	= Square centimetres	0.309 6692	31	200
Square feet	- x 0.0929	= Square metres	2.968 0317	140	13
Square yards	- x 0.8361	= Square metres	1.922 2717	61	51
Square miles	- x 2.589	= Square kilometres	0.413 2996	112	290
Square centimetres	- x 0.155	= Square inches	1.190 3308	200	31

CONVERSION TABLES

531.9

AREA—continued.

Square metres	-	× 10 ⁻⁷⁶⁴	-	= Square feet	-	1.031	9708	13	140
Square metres	-	× 1.196	-	= Square yards	-	0.077	7283	51	61
Square kilometres	-	× 0.3862	-	= Square miles	-	1.586	7004	290	112

Alter two decimal places for each division of the metre.

VOLUME—

Cubic inches	-	× 16.387	-	= Cubic centimetres	-	1.214	5038	5	82
Cubic feet	-	× 0.0283	-	= Cubic metres	-	2.452	0475	600	17
Cubic feet	-	× 28.317	-	= Litres (dm ³)	-	1.452	0475	3	85
Cubic yards	-	× 0.7646	-	= Cubic metres	-	1.883	4113	85	65
Gallons	-	× 4.545	-	= Litres	-	0.057	6259	46	209
Gallons	-	× 1.2	-	= U.S. gallons	-	0.079	5101	5	6
Cubic centimetres	-	× 0.06102	-	= Cubic inches	-	2.785	4962	82	5
Cubic metres	-	× 35.3145	-	= Cubic feet	-	1.547	9525	17	600
Litres (dm ³)	-	× 0.0353	-	= Cubic feet	-	2.547	9525	85	3
Cubic metres	-	× 1.308	-	= Cubic yards	-	0.116	5887	85	65
Litres	-	× 0.2199	-	= Gallons	-	1.342	3741	209	46
U.S. gallons	-	× 0.83	-	= Gallons	-	1.920	4899	6	5

Alter three decimal places for each division of the metre, and one place of decimals for each division of the litre.

WEIGHT—

Ounces	-	× 28.35	-	= Grammes	-	1.452	5459	67	1900
Ounces	-	× 0.02835	-	= Kilogrammes	-	2.452	5459	670	19
Pounds	-	× 0.4535	-	= Kilogrammes	-	1.656	6638	75	34
Hundredweights	-	× 50.802	-	= Kilogrammes	-	1.705	8838	5	254
Tons	-	× 1.016	-	= Tonnes	-	0.006	9138	62	63

MULTIPLIERS AND SLIDE RULE CONVERSIONS—Continued

Known Quantity (on Slide).	Multiplier.	Required Quantity (on Rule).	Logarithm.	On Slide.	On Rule.
WEIGHT—continued.					
Grammes -	-	-	2.547 4541	1900	67
Kilogrammes -	× 0.03527	= Ounces -	-	-	670
Kilogrammes -	× 35.27	= Ounces -	1.547 4541	19	75
Kilogrammes -	× 2.2046	= Pounds -	0.343 3342	34	5
Kilogrammes -	× 0.01968	= Hundredweights -	2.284 1162	254	62
Tonnes -	× 0.9842	= Tons -	1.983 0862	63	-
Alter one decimal place for each division of the gramme.					
VELOCITY—					
Feet per second -	× 18.288	= Metres per minute -	1.282 1671	7	128
Feet per second -	× 0.682	= Miles per hour -	1.853 6687	44	30
Feet per minute -	× 0.01137	= Miles per hour -	2.055 5174	264	3
Yards per minute -	× 0.03409	= Miles per hour -	2.532 6270	88	3
Miles per hour -	× 26.83	= Metres per minute -	1.428 4984	12	322
Miles per hour -	× 0.447	= Metres per second -	1.650 3471	38	1.7
Knots -	× 1853	= Metres per hour -	3.267 9194	33	380
Metres per minute -	× 0.0547	= Feet per second -	2.737 8329	128	7
Miles per hour -	× 1.467	= Feet per second -	0.166 3313	15	22
Miles per hour -	× 88	= Feet per minute -	1.944 4827	3	264
Metres per minute -	× 0.373	= Miles per hour -	2.571 5016	322	12
Metres per second -	× 2.237	= Miles per hour -	0.349 6529	1.7	38
Metres per hour -	× 539.611	= Knots -	2.732 0806	380	3.3
PRESSURE—					
Pounds per square inch ×	0.0703	= Kilog. per sq. cm. -	2.846 9966	128	9
Pounds per square inch ×	0.0681	= Atmospheres -	2.832 7740	485	33

CONVERSION TABLES

531.9

PRESSURE—continued.

Pounds per square inch	× 2.306	-	= Water head, feet	-	13	30
Pounds per square inch	× 0.703	-	= Water head, metres	-	33	25
Pounds per square inch	× 2.036	-	= Inches, mercury gauge	-	25	51
Pounds per square inch	× 27.69	-	= Inches, water gauge	-	13	360
Pounds per square foot	× 4.882	-	= Kilos per square metre	-	51	249
Pounds per lineal foot	× 1.488	-	= Kilos per lineal metre	-	41	61
Pounds per lineal mile	× 0.282	-	= Kilos per kilometre	-	71	20
Pounds per cubic foot	× 16.018	-	= Kilos per cubic metre	-	39	625
Atmospheres	× 14.696	-	= Pounds per square inch	-	34	500
Atmospheres	× 29.921	-	= Inches, mercury gauge	-	1	30
Atmospheres	× 1.033	-	= Kilos per sq. metre	-	39	625
Kg. per sq. centimetre	× 0.9674	-	= Atmospheres	-	92	89
Kg. per square metre	× 0.2048	-	= Pounds per square foot	-	425	87
Kg. per lineal metre	× 0.6719	-	= Pounds per lineal foot	-	61	41
Kg. per kilometre	× 3.548	-	= Pounds per lineal mile	-	20	71
Kg. per cubic metre	× 0.0624	-	= Pounds per cubic foot	-	625	39
Kg. per sq. centimetre	× 14.223	-	= Pounds per square inch	-	9	128
Water head, feet	× 0.434	-	= Pounds per square inch	-	30	13
Water head, metres	× 1.422	-	= Pounds per square inch	-	25	33
Inches, mercury gauge	× 0.491	-	= Pounds per square inch	-	51	25
Inches, mercury gauge	× 14	-	= Inches, water gauge	-	1	14
Inches, water gauge	× 0.03615	-	= Pounds per square inch	-	360	13
Inches, water gauge	× 0.0715	-	= Pounds per square inch	-	14	1
Inches, mercury gauge	× 0.0634	-	= Inches, mercury gauge	-	30	1
Inches, mercury gauge	× 0.0634	-	= Atmospheres	-	30	1

Alter two places of decimals for each division of the metre.

VOLUME AND WEIGHT—

Cubic feet of water	× 62.428	-	= Weight in pounds	-	17	1080
Cubic feet of water	× 6.229	-	= Gallons (imperial)	-	17	106

MULTIPLIERS AND SLIDE RULE CONVERSIONS—Continued

Known Quantity (on Slide).	Multiplier.	Required Quantity (on Rule).	Logarithm.	On Slide.	On Rule.
VOLUME AND WEIGHT—continued.					
Gallons of water . . .	$\times 4.546$	= Weight, kilos . . .	0.657 6259	108	490
Pounds of water (fresh) $\times 1.027$		= Pounds of water (sea) . . .	0.431 3838	38	39
Weight in pounds . . .	$\times 0.0161$	= Cubic feet of water . . .	2.204 6183	1060	17
Gallons (imperial) . . .	$\times 0.161$	= Cubic feet of water . . .	1.204 6183	106	17
Weight, kilogrammes . . .	$\times 0.22$	= Gallons of water . . .	1.342 3741	490	108
Pounds of water (sea) . . .	$\times 0.973$	= Pounds of water (fresh) . . .	1.988 1128	39	38
WORK—					
British thermal units $\times 0.252$		= Great calories . . .	1.401 3933	250	63
(778 foot-pounds)					
British thermal units $\times 0.555$		= Calories per kilogramme	1.741 1516	9	5
per pound					
Foot-pounds . . .	$\times 0.1382$	= Kilogrammetres . . .	1.140 5080	340	47
Horse-power . . .	$\times 1.0138$	= Force de cheval . . .	0.005 9830	72	73
Pounds per horse-power $\times 0.447$		= Kilos per cheval . . .	1.650 3075	300	134
Horse-power per hour $\times 0.746$		= Kilowatts (B. of T. U.) . . .	1.872 7388	134	100
Watts . . .	$\times 0.00134$	= Horse-power . . .	3.127 4653	5	0.067
Great calories . . .	$\times 3.968$	= British thermal units . . .	0.598 6067	63	250
(one calorie = 0.001 of a great calorie)					
Calories per kilogramme $\times 1.8$		= Brit. thermal units per lb. . .	0.255 2725	5	9
Kilogrammetres . . .	$\times 7.233$	= Foot-pounds . . .	0.859 3185	47	340
Force de cheval . . .	$\times 0.9863$	= Horse-power . . .	1.994 0170	73	72
Kilos. per cheval . . .	$\times 2.239$	= Pounds per horse-power . . .	0.330 0541	134	300
Kilowatt-hrs. (B. T. U.) $\times 1.34$		= Horse-power per hour . . .	0.127 1048	100	134
Horse-power . . .	$\times 745.65$	= Watts . . .	2.872 5348	0.067	5

DECIMAL EQUIVALENTS OF FRACTIONS 531.9

DECIMAL EQUIVALENTS OF FRACTIONS

Ths. 4	Ths. 8	Ths. 16	Nds. 32	Ths. 64	Decimal.	Ths. 4	Ths. 8	Ths. 16	Nds. 32	Ths. 64	Decimal.
				1	.015625					33	.515625
			1	...	.03125				17	...	.53125
			...	3	.046875				...	35	.546875
		1	...	...	.0625			9	...	...	.5625
			...	5	.078125				...	37	.578125
			3	...	.09375				19	...	.59375
			...	7	.109375				...	39	.609375
	1	...	...	...	.125		5	...	...	...	.625
			...	9	.140625				...	41	.640625
			5	...	.15625				21	...	.65625
			...	11	.171875				...	43	.671875
		3	...	...	.1875			11	...	...	.6875
			...	13	.203125				...	45	.703125
			7	...	.21875				23	...	.71875
			...	15	.234375				...	47	.734375
$\frac{1}{4}$	...	...	...	...	.25	$\frac{3}{4}$	...	...	...	...	.75
			...	17	.265625				...	49	.765625
			9	...	.28125				25	...	.78125
			...	19	.296875				...	51	.796875
		5	...	...	.3125			13	...	...	.8125
			...	21	.328125				...	53	.828125
			11	...	.34375				27	...	.84375
			...	23	.359375				...	55	.859375
	3	...	...	...	.375	7	...	...	...	...	.875
			...	25	.390625				...	57	.890625
			...	13	.40625				29	...	.90625
			...	27	.421875				...	59	.921875
		7	...	...	.4375			15	...	...	.9375
			...	29	.453125				...	61	.953125
			15	...	.46875				31	...	.96875
			...	31	.484375				...	63	.984375
$\frac{1}{2}$	...	...	...	...	.5	1	...	...	...	...	1.0

SPECIFIC GRAVITIES AND MELTING POINTS

	Specific Gravity.	Weight per Cub. In. (Lbs.)	Melting Point. °C.
Aluminium - - -	2.60	.094	600
Antimony - - -	6.70	.242	440
Bessemer soft steel - - -	7.80	.282	1,450
Bismuth - - -	9.80	.354	260
Brass - - -	8.4	.300	800
Copper - - -	8.91	.322	1,050
Iron (pure) - - -	7.78	.282	1,500
Lead - - -	11.4	.410	326
Magnesium - - -	1.74	.063	...
Mercury - - -	13.6	.490	- 39
Nickel - - -	8.9	.321	1,500
Platinum - - -	21.2	.765	1,775
Silver - - -	10.5	.379	950
Tin - - -	7.3	.264	230
Zinc - - -	7.1	.256	415
Potassium - - -	0.865	.031	62.5
Sodium - - -	0.98	.035	95.6
Manganese - - -	7.2	.026	...
Sulphur - - -	2.07	.075	114.5

WEIGHT AND SPECIFIC GRAVITY OF METALS

Metal.	Specific Gravity.	Weight of 1 Cub. Ft. in Lbs.	Weight of 1 Cub. In. in Lbs.
Aluminium, cast - - -	2.56	160	0.0927
Aluminium, wrought - - -	2.67	167	0.0968
Brass, cast - - -	8.10	505	0.293
Brass, sheet - - -	8.45	527	0.305
Copper, sheet - - -	8.905	549	0.318
Iron, wrought - - -	7.698	480	0.278
Iron, cast - - -	7.217	450	0.261
Phosphor bronze, cast - - -	8.60	536.8	0.310
Steel - - -	7.852	489.6	0.283
Tin - - -	7.409	462	0.268
Duralumin - - -	2.85	178	0.1029
Gun metal - - -	8.57	534	0.31
Lead - - -	11.35	708	0.409

WEIGHTS OF LIQUIDS AND GASES 532.42.08

WEIGHT OF LIQUIDS

	Specific Gravity.	Weight of 1 Cub. Ft. (Lbs.)	Weight of 1 Cub. In. (Lbs.)
Water	1.00	62.425	.036
Acetic acid	1.06	66	.038
Alcohol, absolute	0.792	49	.028
" proof	0.916	57	.033
Benzene	0.900	56	.033
Ether	0.716	45	.026
Glycerine	1.260	79	.046
Hydrochloric acid, concentrated	1.20	75	.043
Iodine	8.72	544	.315
Linseed oil	0.94	58	.034
Mercury	13.60	849	.491
Nitric acid, concentrated	1.217	75	.044
Olive oil	0.92	57	.033
Paraffin, American	0.815	51	.029
" Russian	0.825	52	.030
Petrol	0.70	44	.025
Petroleum, Penn., heavy	0.886	55	.032
" Caucasian, heavy	0.938	59	.034
" " light	0.884	55	.032
" refuse	0.938	59	.034
Sea water	1.027	64	.037
Sulphuric acid, concentrated	1.84	115	.066

WEIGHT OF GASES

533.1

	Specific Gravity.	Weight of 1 Cub. Ft. (Lbs.)	Weight of 1 Cub. In. (Lbs.)
Carbonic acid	.00197	.123	.000071
Hydrogen	.0000895	.0056	.0000032
Nitrogen	.00125	.078	.000045
Oxygen	.00143	.089	.000051
Coal gas	.0004	.034	.00002
Air	.001293	.08072	.00004655

DENSITY OF THE AIR

This is required for the purpose of calculating the lifting power of a balloon, and also for checking the performance of an aeroplane. The formula is:—

$$\rho = \rho_0 \frac{p - \frac{3}{8}e}{p_0} \times \frac{T_0}{T}$$

Where

ρ is the density to be calculated.

ρ_0 is the density of perfectly dry air under the conditions,

$p_0 = 1,000$ mb., $29\cdot53$ in., and $T_0 = 290a$, when

$\rho_0 = 1,201$ g/m³.

p is the barometric pressure in mb.

e is the pressure of aqueous vapour.

The following is an example of the determination of the density of air from a reading of the barometer and wet and dry bulb thermometers.

Barometer corrected for temperature $1,010\cdot1$ mb. ($29\cdot83$ in.).

Dry bulb " " " $285\cdot8a$. ($55\cdot1^\circ$ F.).

Wet bulb " " " $281\cdot3a$. ($47\cdot0^\circ$ F.).

Vapour pressure from humidity tables = $8\cdot2$ mb. ($0\cdot239$ in.).

$$\rho_0 = 1,201 \text{ g/m}^3$$

$$\rho = 1,201 \times \frac{1010\cdot1 - 8\cdot2}{1000} \times \frac{290}{285\cdot8} \text{ g/m}^3$$

$$= 1,227 \text{ g/m}^3$$

or $0\cdot0766$ lb. per cubic foot.

Note.—One grain per cubic foot is equivalent to $2\cdot29$ g/m³.

STANDARD DENSITY

The standard adopted by the R.A.F. for dry air at 760 mm. ($29\cdot2$ in.) pressure and 16° C., is $1\cdot221$ kgm. per cu. m. Air speed indicators are so made as to indicate correctly at this density, assuming that:—

$$p = \frac{1}{2} \rho V^2$$

Where V is the air speed, p the pressure, and ρ the standard density.

DENSITIES

*Hydrogen (dry)	-	-	$88\cdot74$ g/m ³
*Carbonic acid gas (dry)	-	-	$1,953$ g/m ³
Water	-	-	$1,000$ g/cc (at $277a$.)
Sea water	-	-	$1\cdot01$ to $1\cdot05$ g/cc.
Mercury	-	-	$13\cdot596$ g/cc (at $273a$.)
Petrol	-	-	$0\cdot68$ to $0\cdot72$ g/cc.

* At a pressure of $1,000$ mb. and temperature of 273 degrees absolute centigrade.

THE ANEROID BAROMETER

533-11

MEAN ATMOSPHERIC PRESSURE, TEMPERATURE, AND DENSITY AT VARIOUS HEIGHTS ABOVE SEA LEVEL

(W. H. Dines)

Height.		Mean.		
Km.	Fect.	Pressure in mb.	Temp. Deg. Cent. Absolute.	Density in Kgm. per cu. m.
0	0	1,014	282	1.253
1	3,280	900	278	1.128
2	6,560	795	273	1.014
3	9,840	699	268	0.909
4	13,120	615	262	0.818
5	16,400	538	255	0.735
6	19,680	469	248	0.658
7	22,960	407	241	0.589

The Barometer

533-4

The barometer is used to determine the pressure of the atmosphere; by finding the difference in pressure at two places, their difference in height above the sea level can be determined. When a barometer is employed specially for measuring heights, it is often called an "altimeter," or "altitude barometer." As a mercury column type of instrument is impracticable on an aeroplane, the usual pattern used by aviators is operated on the aneroid principle, and has one or more exhausted boxes coupled up together. The motion of the boxes is recorded by a pointer worked by a series of multiplying levers.

The characteristics of an aviator's altimeter are sensitiveness, ability to withstand vibration, a minimum lag, no acceleration error, and an open scale with equal divisions.

The Aneroid Barometer

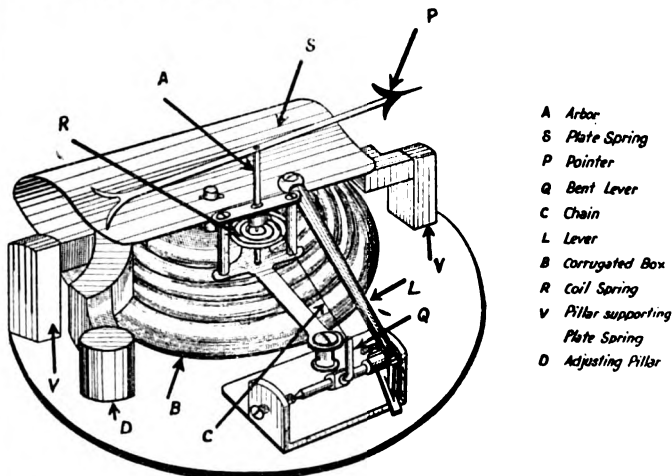
533-43

The aneroid barometer consists in principle of a round, flat, exhausted box to which is attached a spring. The motion of the top and bottom of the box under varying atmospheric pressure is recorded by the spring, which moves a pointer by means of a lever and chain. The figure will explain the action of the instrument.

The spring *s* rests in gudgeons in the pillars *v*, *v*, and is attached to a socket in the top of the box *B*. Motion of the spring is communicated through the lever *L* and the bent lever *Q* to the chain *c*, which is wound upon the arbor *A*, carrying the pointer *P*. When the box is compressed by an increase in the atmospheric pressure, the motion of the arbor *A* winds up the coil spring *R*;

when the pressure decreases, the relaxation of the spring *s* acting through the levers slackens the chain *c*, which is made taut again by the unwinding of the coil spring *r*. The adjusting pillar *d* is fastened to the spring *s*, and is moved by a screw passing through the base plate of the instrument, so as to bring the reading of the instrument into accordance with that of a standard mercury barometer.

Aneroid Correction Factors.—As it is the custom to graduate



- A Arbor
- S Plate Spring
- P Pointer
- Q Bent Lever
- C Chain
- L Lever
- B Corrugated Box
- R Coil Spring
- V Pillar supporting Plate Spring
- D Adjusting Pillar

these instruments at 50° F. (10° C.), a correction has to be applied for other temperatures, in accordance with the formula:—

$$H = \frac{273 + t}{283} h,$$

Where *H* = true difference in height between any two points.
t = average temperature in degrees C. between the points.
h = the difference in height indicated by the aneroid.

At	70° F.	the Correction Factor is	1.040
"	50°	"	1.000
"	30°	"	0.961
"	10°	"	0.922
"	-10°	"	0.883

So that if a climb is made through 1,000 ft., as given by an aneroid, when the average temperature is 30° F., the actual distance is only $1,000 \times 0.961 = 961$ ft.

The Chemical Weather-glass

A weather-glass which will give indications of weather changes may be made as under :—

Camphor	-	-	-	-	-	-	-	2 dr.
Potass. nitrate (nitre)	-	-	-	-	-	-	-	$\frac{1}{2}$ „
Ammon. chloride (sal-ammoniac)	-	-	-	-	-	-	-	$\frac{1}{2}$ „
Absolute alcohol	-	-	-	-	-	-	-	2 oz.
Water	-	-	-	-	-	-	-	2 „

The liquid is usually placed in a glass tube about 10 in. long by $\frac{3}{4}$ in. diameter, which must be nearly filled, corked, sealed, and then hung vertically on a wall facing north, so as to be shaded from the sun. The different appearances are as under :—

Liquid clear	-	-	-	Bright weather.
Liquid dim	-	-	-	Rain.
Liquid dim, with small stars in motion	-	-	-	Thunderstorms.
Small dots	-	-	-	Damp weather, with fog.
Large flakes	-	-	-	Dull weather, snow in winter.
Crystals at bottom	-	-	-	Frost in winter.
Threads in upper portion	-	-	-	Wind.
Small stars	-	-	-	On bright days in winter, snow on one or two days.

533-45

Radiator Transmitting Thermometers.—These are employed to indicate to the pilot when a water-cooled engine is in danger of overheating, and whether there is any loss by boiling in the water-cooling system. The bulb of the thermometer is placed either in the uptake pipe from the water jacket, or in the upper part of the radiator. They consist of a cylindrical metallic bulb filled with ether, partly as liquid and partly as vapour. A fine bored tube runs down the centre of the bulb so as to end below the level of the liquid, and is connected at its other end to a Bourdon pressure gauge on the instrument board. The tube and Bourdon coil are also filled with ether. The pressure in the bulb is, therefore, that of ether vapour in contact with its own liquid. This pressure is transmitted through the tube to the Bourdon gauge, the variation in pressure due to the difference of the level of the gauge and the tube being negligible compared with the vapour pressure in the bulb. Now the pressure of a liquid in contact with its own vapour is known to depend only on the temperature, and not on the volume occupied. Hence it is not affected by the exact amount of ether in the bulb, or by any changes of volume of the latter and of the tube and gauge, due to temperature or outside pressure. This vapour pressure can, therefore, be

used as an index for temperature, and the gauge is graduated to read accordingly.

A thermometer of this type over-reads, in accordance with the following table, as the altitude increases and the atmospheric pressure falls, since it indicates the difference between the vapour pressure and the atmospheric pressure.

Temperature.	Centigrade.	50°	60°	70°	80°	90°	100°
Indicated temperature	at 10,000 ft.	55°·8	64°·5	73°·6	82°·9	92°·4	102°·0
	at 20,000 ft.	59°·7	67°·5	76°·1	85°·0	94°·1	103°·4

BOILING POINTS OF WATER

The fall in the boiling point is about 1° C. for every 1,000 feet of rise.

Height in Feet.	0	5,000	10,000	15,000	20,000
Boiling pt. in degrees C.	100°	94°·9	90°·0	85°·25	80°·6

In consequence of the combination of the above two effects, the boiling points, as indicated by the thermometer, are as follows :—

Height in Feet.	0	5,000	10,000	15,000	20,000
Indicated boiling point in degrees C.	100°	96°·1	92°·4	88°·9	85°·5

DE-DA (Detachable Data) System.
R. Barlow Matthews' Patents (provisionally protected). U.S. Patents applied for.

AIR PRESSURE AND RESISTANCE

General Considerations—Head Resistance of Planes—Of other Bodies—Skin Friction—Effect of Airscrew Draught—Pressure on Inclined Surfaces—Cambered Planes—Loading of Wings—Factors of Safety—Multiplying Factors to Correct Results of Model Experiments—A Modern Wing Section—Animal Flight.

THE resistance experienced by the parts of an aeroplane in flight is due to (a) distortion of the free flow of the air, otherwise "streamline flow," and (b) "skin friction" on surfaces tangential to the flow of air. It is difficult to study separately these two kinds of resistances. The resistance of a flat plate placed at right angles to a flow of air is mostly due to (a), but still a slight amount of skin frictional resistance is present. Likewise the same plate placed edgewise in a current of air experiences resistance, mostly due to (b), but as it is bound to have some thickness, however small, distortion of the free flow of air must occur. A plate inclined at an angle to the flow of air evidently experiences resistance of both kinds. The difficulty in separating the two kinds has necessitated numerous experiments to determine the total resistance of the various parts of the aeroplane.

The total resistance of an aeroplane is conveniently summed up under two heads—(i.) that due to the "drag" of the wings or "wing resistance"; (ii.) that due to other parts, such as body, chassis, struts, wires, etc., usually termed "head resistance."

Head Resistance may well be considered first: the only trustworthy values are those obtained from experiment. Three main methods of experiment have been used: (1) The "whirling table," in which the body experimented upon is placed on the end of an arm rotating rapidly in the air. (2) The "wind tunnel," in which the bodies are mounted in a special channel, through which a current of air is made to pass. (3) The method used by M. Eiffel, in which plates were allowed to fall from a height, and their resistance calculated from measurements of their velocity.

The whirling table method, used notably by Dines and Langley, cannot be relied upon to give accurate absolute values, although useful for comparative tests. The wind tunnel method is reliable if the surface experimented on is not more than 0.7 per cent. of the area of the channel; a more uniform current can be obtained by drawing the air through the channel than by blowing it through.

Eiffel, Stanton, Bairstow, and Riabouchinsky are the chief experimenters by this method.

All experimenters are agreed that :—

- (1) For very low speeds - - - - - $R \propto V$
- (2) For ordinary speeds and up to about
160 ft. per second - - - - - $R \propto V^2$
- (3) For speeds above 160 ft. per second - $R \propto V^n$ where n is
greater than 2.

Where R = head resistance due to an air current of velocity V .

It is probable that as velocities comparable with that of sound are reached the index n in (3) above increases very rapidly.

The resistance per unit of area appears to vary somewhat with the size of the surface exposed to the air, being rather less with small plates, and increasing to a limiting value when the surface is about 5 sq. ft.

For ordinary velocities, therefore, the law of atmospheric resistance to a surface at right angles to an air current may be given as—

$$R = z \cdot \frac{w}{g} \cdot S \cdot V^2,$$

Where R = head resistance.

z = a coefficient, varying slightly with the size of surface.

w = weight of unit volume of air (density).

S = area of normal surface.

V = velocity of air current.

g = the acceleration of gravity.

It may be noticed that this formula holds with the same coefficient for fluids of different densities if the appropriate values for the densities are introduced into the equation, if the viscosities are the same.

The form in which the equation is directly of use is that in which z , g , and w are incorporated in a single constant; writing K for $z \cdot \frac{w}{g}$, we have—

$$R = KSV^2.$$

It should be noticed that the value of K is affected by the height of the barometer and by the temperature, since alterations in either of these cause variations in the density of the air, whose value is included in the constant K . The following formula is given by Eiffel :—

$$\frac{dK}{K} = \frac{dH}{H} - \frac{dT}{273 + T}$$

Where H = mean pressure in millimetres of mercury.

T = mean temperature in degrees centigrade.

And dK , dH , dT are the small changes in K , H , and T respectively.

This means that a decrease in temperature from 18° to 15° C. (64.4° to 59° F.), or a rise in the barometric pressure of about 7 mm., will cause an increase in the value of K of, roughly, 1 per cent.

The following tables give the results of the most important experiments which have been performed. The values for the constant are given for different notations, as under :—

$$p = z \frac{w}{g} v^2 \quad \text{Where } z \text{ is in absolute units (and } p, w, s, v, \text{ and } g \text{ in consistent units).}$$

$$P = KSV^2 \quad P \text{ in lbs. weight; } S \text{ in square feet; } V \text{ in miles per hour.}$$

$$P_1 = K_1 S_1 V_1^2 \quad P_1 \text{ in lbs. weight; } S_1 \text{ in square feet; } V_1 \text{ in feet per second.}$$

$$P_2 = K_2 S_2 V_2^2 \quad P_2 \text{ in kilogrammes weight; } S_2 \text{ in square metres; } V_2 \text{ in kilometres per hour.}$$

$$P_3 = K_3 S_3 V_3^2 \quad P_3 \text{ in kilogrammes weight; } S_3 \text{ in square metres; } V_3 \text{ in metres per second.}$$

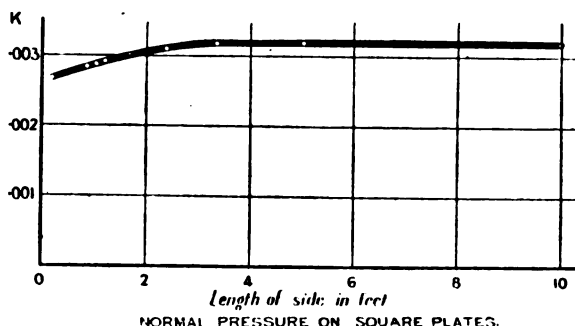
The conversion factors are as follows :—

$$\begin{aligned} z &= 191.9 K, & = 412.8 K_1, & = 103.7 K_2, & = 8.00 K_3, \\ K &= 2.151 K_1, & = 5304 K_2, & = 0.4092 K_3, \\ K_1 &= 2.466 K_2, & = 0.190 K_3, \\ K_2 &= 0.7716 K_3. \end{aligned}$$

COEFFICIENTS OF NORMAL PRESSURE ON SQUARE PLATES

Experi- menter.	z.	K.	K ₁ .	K ₂ .	K ₃ .	Size of Plate.	Remarks.
						Ft. In.	
Stanton	.52	.0027	.00126	.0051	.066	0 2 sq.	Wind tunnel method.
Cailletet	.55	.0028	.00133	.0054	.070	0 6 "	" "
Eiffel	.55	.0028	.00133	.0054	.070	0 10 "	Falling plate method.
Dines	.56	.0029	.00135	.0055	.071	1 0 "	Corrected value.
Eiffel	.56	.0029	.00136	.0055	.071	1 2 "	Whirling table method.
"	.59	.0030	.00142	.0058	.075	1 8 "	Falling plate method.
"	.61	.0031	.00147	.0059	.077	2 3 "	"
"	.62	.0032	.00150	.0061	.079	3 3 "	"
Stanton	.62	.0032	.00148	.0060	.078	5 0 "	Plates exposed to wind.
"	.62	.0032	.00149	.0060	.078	10 0 "	"

The subjoined curve, due to Dr Stanton, shows the increase in K with the size of the plate up to a limiting value at $\cdot 0032$ for plates of above 3 ft. 6 in. side.



Messrs Bairstow and Booth, of the National Physical Laboratory, have recently given the following formula for the resistance of a square plate in a current of air:—

$$R = \cdot 00126 (v)^2 + \cdot 0000007 (v)^3,$$

Where v is in feet per second, and equals velocity of air current.
 l is in feet, and equals the length of side of the plate.

Circular Plates.—The pressure on circular plates varies with their size in a similar manner. Eiffel's experiments gave results as under:—

NORMAL PRESSURE ON CIRCULAR PLATES (Eiffel)

Area.	z .	K .	K_1 .	K_2 .	K_3 .
Sq. Ft.					
$\cdot 67$	$\cdot 54$	$\cdot 0028$	$\cdot 00129$	$\cdot 0052$	$\cdot 068$
$1\cdot 34$	$\cdot 57$	$\cdot 0029$	$\cdot 00135$	$\cdot 0055$	$\cdot 071$
$2\cdot 69$	$\cdot 59$	$\cdot 0030$	$\cdot 00141$	$\cdot 0057$	$\cdot 074$
$5\cdot 38$	$\cdot 62$	$\cdot 0032$	$\cdot 00147$	$\cdot 0059$	$\cdot 077$
$10\cdot 76$	$\cdot 62$	$\cdot 0032$	$\cdot 00147$	$\cdot 0059$	$\cdot 077$

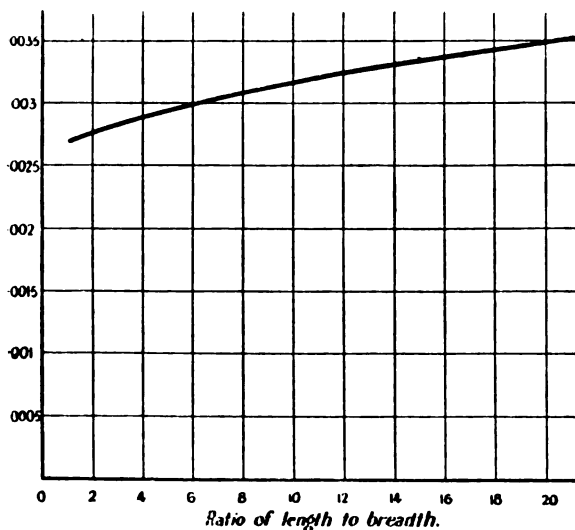
The coefficient increases with the size of the plate, as with square plates, and to the same limiting value.

Rectangular Plates.—In the case of rectangular plates the coefficient is affected by the ratio of the length of the plate to its breadth. The following results were obtained by Dr Stanton, using small plates in a wind tunnel.

NORMAL PRESSURE ON SMALL RECTANGULAR PLATES

Size of Plate.	Ratio, Length to Breadth.	K.
In.		
2 × 2	1	·0027
3 × 1	3	·0028
2½ × ½	5	·0029
5 × ½	10	·0032
6 × 3	20	·0035

These values are plotted below.



Summary—Air Resistance of Planes.—The conclusion to be drawn from the foregoing tables is that for calculations as to the resistance experienced by a surface normal to the wind, the value of K may be taken as 0.003 for either square or circular plates of medium dimensions; for rectangular plates K is more approximately $0.003 + 0.000025n$, where n is the ratio of the longer to the shorter

side. In the case of aeroplane calculations, as the surfaces are always comparatively large, K may be taken as 0.0032 at normal temperature and pressure (N.T.P.), viz., 60° F. (15.6° C.) and 29.92 in. (760 mm.) of mercury. From this:—

$$R = 0.0032 SV^2,$$

Where

R is in lbs. weight. S is in square feet. V is in miles per hour.

The following tables give the resistance calculated by this formula and by the corresponding formula $R = 0.00149 v_1^2$, where v_1 is in feet per second.

AIR RESISTANCE OF FLAT PLATES NORMAL TO WIND

Velocity.	Pressure.	Velocity.	Pressure.	Velocity.	Pressure.
Miles per Hour.	Lbs. per Ft. ²	Miles per Hour.	Lbs. per Ft. ²	Miles per Hour.	Lbs. per Ft. ²
10	.320	41	5.379	72	16.589
11	.387	42	5.645	73	17.052
12	.461	43	5.917	74	17.524
13	.541	44	6.195	75	18.000
14	.627	45	6.480	76	18.483
15	.720	46	6.771	77	18.972
16	.819	47	7.068	78	19.469
17	.925	48	7.372	79	19.971
18	1.037	49	7.683	80	20.480
19	1.155	50	8.000	81	20.997
20	1.280	51	8.323	82	21.517
21	1.411	52	8.652	83	22.045
22	1.549	53	8.989	84	22.579
23	1.693	54	9.331	85	23.120
24	1.843	55	9.680	86	23.666
25	2.000	56	10.035	87	24.221
26	2.163	57	10.397	88	24.780
27	2.333	58	10.764	89	25.349
28	2.509	59	11.139	90	25.920
29	2.691	60	11.520	91	26.501
30	2.880	61	11.907	92	27.085
31	3.075	62	12.300	93	27.678
32	3.277	63	12.701	94	28.276
33	3.485	64	13.107	95	28.881
34	3.699	65	13.520	96	29.491
35	3.920	66	13.937	97	30.109
36	4.147	67	14.364	98	30.734
37	4.381	68	14.796	99	31.360
38	4.621	69	15.237	100	32.000
39	4.867	70	15.680	120	46.083
40	5.120	71	16.130		

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AIR RESISTANCE OF FLAT PLATES NORMAL TO WIND

Velocity.	Pressure.	Velocity.	Pressure.	Velocity.	Pressure.
Ft. per Sec.	Lbs. per Ft. ²	Ft. per Sec.	Lbs. per Ft. ²	Ft. per Sec.	Lbs. per Ft. ²
16	.38	62	5.73	108	17.38
18	.48	64	6.10	110	18.03
20	.60	66	6.49	112	18.69
22	.72	68	6.89	114	19.36
24	.86	70	7.30	116	20.05
26	1.01	72	7.72	118	20.74
28	1.17	74	8.16	120	21.46
30	1.34	76	8.61	122	22.18
32	1.53	78	9.06	124	22.91
34	1.72	80	9.54	126	23.65
36	1.93	82	10.02	128	24.41
38	2.15	84	10.51	130	25.18
40	2.38	86	11.02	132	25.96
42	2.63	88	11.54	134	26.75
44	2.88	90	12.07	136	27.56
46	3.15	92	12.61	138	28.38
48	3.43	94	13.17	140	29.20
50	3.73	96	13.73	142	30.04
52	4.03	98	14.31	144	30.90
54	4.34	100	14.90	146	31.76
56	4.67	102	15.50	148	32.64
58	5.01	104	16.11	150	33.52
60	5.36	106	16.74	200	59.60

The equation previously given may also be expressed in foot-second units:—

$$R = k \frac{v^2}{g} WS,$$

Where v is the velocity in *feet per second*.

W is the weight of the air in lbs. per cubic foot.

g is 32.2.

S is the area in square feet.

k is 0.625. (From the experiments of Eiffel and Stanton.)

Substituting, the equation becomes:—

$$R = 0.0194 WSv^2 \text{ (lbs.)}$$

Perforation in Plates.—It has been shown that a considerable number of perforations may be made in a plate without seriously altering the air pressure upon it.

Remaining Area of Plate.	Ratio of Pressure to Pressure on Unperforated Plate.
1.0	1.0
.90	1.0
.8	.9
.7	.8
.6	.7
.5	.6
.4	.5
.3	.4
.2	.3
.1	.2

Shielding.—The results of experiments on the shielding effect of one plate placed in front of another are given below, for equal circular plates:—

Distance apart of Plates, in terms of the Diameter.	Ratio of Air Pressure on both Plates to that on a Single Isolated Plate.	
	Eiffel (Plate 15½ in. diameter).	Stanton (Plate 1.97 in. diameter).
0.5	.96	...
1	.83	...
1.5	.75	less than .75
2.15	...	1
5	...	1.78
10	...	2

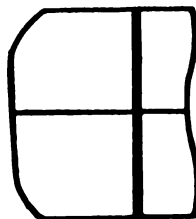
Stanton found similar results with square plates, but he noticed a considerably less shielding effect in the case of rectangles with a high ratio of length to breadth.

Distribution of Pressure on Normal Plates.—According to Stanton, the compression at the centre of the front face of a plate in a current of air is the same for all surfaces, and is equal to $\frac{\delta}{2\gamma} V^2$.

He found the suction on the back face practically uniform except near the edges, but the value varies according to the form of the surface. The figure represents the pressure on the centre line of a rectangle, 3 by 1 in.



direction of
air current.



The leakage of air over the edges is clearly shown by the diminu-

DISTRIBUTION OF PRESSURE

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tion of pressure; the large effect of suction on the back of the plate is also shown.

Experiments made by Nipher show much the same results. The tables below were calculated by Eiffel from the results of Nipher's experiments; taking 100 as the maximum pressure, the pressures at different points on the plate are shown by proportional figures. 57 per cent. of the total pressure was found to be on the front face, and 43 per cent. on the back.

FRONT FACE

53	57	57	57	57	57	57	57	57	57	57	53
53	79	79	79	79	79	79	79	79	79	79	53
53	82	83	93	93	93	93	93	93	83	82	53
53	82	88	93	100	100	100	100	93	88	82	53
53	82	88	93	96	96	96	96	93	88	82	53
53	82	88	93	100	100	100	100	93	88	82	53
53	82	83	93	93	93	93	93	93	83	82	53
53	79	79	79	79	79	79	79	79	79	79	53
53	57	57	57	57	57	57	57	57	57	57	53

BACK FACE

40	48	48	48	48	48	48	48	48	48	48	40
53	53	53	53	53	53	53	53	53	53	53	53
52	53	55	56	56	56	56	56	56	55	53	53
53	53	62	61	57	57	57	57	61	62	53	53
53	62	62	64	62	62	62	62	64	62	62	53
53	53	62	61	57	57	57	57	61	62	53	53
53	53	55	56	56	56	56	56	56	55	53	53
53	53	53	53	53	53	53	53	53	53	53	53
40	48	48	48	48	48	48	48	48	48	48	40

Head Resistance of Bodies.—The resistance of a body is due to disturbance of the natural or streamline flow of the air, and also to skin friction on its sides. The former component of the resistance is reduced by "fair-shaping" the body, i.e., avoiding all sharp angles which would cause sudden changes in the air flow. The latter component is reduced by shortening the body. This reduction in length may cause some increase in the streamline resistance, and therefore the most suitable length of the body is a matter for compromise determined by experiment.

Streamlines.—A streamline is the locus of the path of a particle of moving fluid: the following expression holds for the total energy of 1 lb. of fluid moving in streamlines:—

$$h + \frac{p}{w} + \frac{v^2}{2g},$$

Where

h is the height above a datum level.

p " pressure.

w " weight per unit volume.

v " velocity of the fluid.

g " acceleration of gravity.

A "streamline form" is a body around which the streamlines are continuous, that is to say, a body which forms no eddies when placed in a current of air. It would appear that the length parallel to the current should be about six times the thickness, with the maximum thickness about a third of the distance from the front.

The reduction of head resistance by making everything possible of streamline form is of the greatest importance, since this reduces the gliding angle, upon which depends the amount of power required to drive the machine through the air; the possibility of "soaring" is also intimately connected with a reduction of the gliding angle.

For each pound saved in resistance, an aeroplane will carry an additional load of 8 lbs., assuming a gliding angle of one in eight; hence the question of resistance needs most careful consideration.

Skin Friction.—The most reliable experiments have been made by Dr Zahm of Washington; he used boards varying in length from 2 to 16 ft., and observed the skin friction at various velocities. His experiments indicate little variation in frictional resistance due to different finishes and conditions of surfaces.

The formula deduced from his experiments for smooth plates is as follows:—

$$R = 0.0000158 \frac{V^{1.85}}{l^{0.57}}$$

Where R = resistance in lbs. per square foot single surface.

l = length of surface parallel to direction of wind.

V = velocity in miles per hour.

SKIN FRICTION

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SKIN FRICTION PER SQUARE FOOT FOR VARIOUS SPEEDS AND LENGTHS OF SURFACE (CHORDS)

Wind Speed.	Average Friction in Lbs. per Square Foot.					
	1-ft. Plane.	2-ft. Plane.	4-ft. Plane.	8-ft. Plane.	16-ft. Plane.	32-ft. Plane.
M. P. H.						
5	0.000303	0.000289	0.000275	0.000262	0.000250	0.000238
10	0.00112	0.00105	0.00101	0.000967	0.000922	0.000878
15	0.00237	0.00226	0.00215	0.00205	0.00195	0.00186
20	0.00402	0.00384	0.00365	0.00349	0.00332	0.00317
25	0.00606	0.00579	0.00551	0.00527	0.00501	0.00478
30	0.00850	0.00810	0.00772	0.00736	0.00701	0.00668
35	0.01130	0.0108	0.0103	0.0098	0.00932	0.00888
40	0.0145	0.0138	0.0132	0.0125	0.0125	0.0114
50	0.0219	0.0209	0.0199	0.0190	0.0181	0.0172
60	0.0307	0.0293	0.0279	0.0265	0.0253	0.0242
70	0.0407	0.0390	0.0370	0.0353	0.0337	0.0321
80	0.0522	0.0500	0.0474	0.0452	0.0431	0.0411
90	0.0650	0.0621	0.0590	0.0563	0.0536	0.0511
100	0.0792	0.0755	0.0719	0.0685	0.0652	0.0622

When applying the above table, it must be borne in mind that the total surface must be taken into consideration, i.e., both top and bottom sides of a plane.

The total resistance of a body of any shape is given by

$$R = K^1 S V^2,$$

Where K^1 is an appropriate constant for the particular shape.

S is the projected area of the body normal to the wind.

V is the velocity of the wind in miles per hour.

In the list of formulae given below, K^1 is the constant just defined, and the ratio $\frac{K^1}{K}$ is calculated for a value of $K = .0032$, unless it is otherwise stated.

TOTAL RESISTANCE COEFFICIENTS FOR VARIOUS BODIES

Body.	K.	K ₁ K	AUTHORITY.	REMARKS.
Aeroplane body or fuselage for tractor machine—fairly streamlined	.0005	.156	N.P.L.	...
Nacelle or egg shaped body	.0004	.125	"	...
Flying boat hull	.00055	.170	"	...
Hydroplane floats	.0005	.156	N.P.L.	...
Struts 3.5 to 1 of streamline section	.0004	.125	"	...
Wires (round)	.0031	1.00	"	See later remarks, p. 39.
Do., streamline	.0008	.40	"	...
Wheels	.0011	.29	N.P.L.	On area to be seen in front elevation of machine.
<i>Miscellaneous bodies—</i>				
Cylinder, side to wind	.0019	.596	Renard	Experiment on cylinder, 15 cm. diameter x 60 cm. long.
Do.	.0017	.53	Eiffel	Experiment on cylinder, 3 cm. diameter x 60 cm. long.
Do.	.0025	.78	"	...
Wire circular	.0027	.87	"	...
Square bar, side to wind	.0039	1.22	Maxim	...
Do., diagonal to wind	.0029	.906	"	...
Sphere	.0006	.189	Renard	...
Do.	.00045	.140	Eiffel	...
Hemisphere, convex side to wind	.0017	.531	Loisel	...
Do.	.0013	.392	Renard	...

RESISTANCE COEFFICIENTS

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Hemisphere, concave side to wind	0.051	1.594	Lösl	...
Do.	0.045	1.406	Renard	...
Do.	0.034	1.063	Eiffel	Original experiment.
Do.	0.038	1.188	"	Latest experiment.
Convex side to wind, base at 45°	0.016	1.500	Lösl	In these cases the formula is $R = K^1 S_1 V^2$, where S_1 is not the projected area, but the area of the base of the hemisphere, i.e., $R = K^1 \pi r^2 V^2$.
Do., base at 22½°	0.014	1.438	"	
Base parallel to direction of wind	0.011	1.344	"	
Concave side to wind, base at 6°	0.013	1.406	"	
Do., base at 22½°	0.022	1.688	"	
Do., base at 45°	0.037	1.156	"	Cylinders with plane ends :— The cylinders experimented on by Dr Stanton were small, and a flat circular plate of the same diameter gave a coefficient $K = 0.028$. K^1 is therefore calculated for this value of K . For M. Eiffel's cylinders the ordinary value $K = 0.032$ has been used, the diameter of the base being 12.5 cm.
Do., base at 60°	0.043	1.344	"	
Cylinder end on—Ratio $\frac{\text{Length}}{\text{Diameter}}$				
= 0.48	0.027	.98	Stanton	
= 0.5	0.029	.91	Eiffel	
= 0.97	0.024	.86	Stanton	
= 1.0	0.028	.88	Eiffel	
= 1.21	0.021	.77	Stanton	
= 1.45	0.016	.64	"	
= 1.5	0.021	.66	Eiffel	
= 2.42	0.019	.70	Stanton	
= 2.68	0.028	.88	Frank	
Ends conical, inclined at 45° to axis	0.019	.59	"	Ratio $\frac{\text{Length}}{\text{Diameter}} = 2.68$; diameter of base 5.6 cm.

(Continued on next page.)

TOTAL RESISTANCE COEFFICIENTS FOR VARIOUS BODIES—Continued

BODY.	K.	$\frac{K^1}{K}$	AUTHORITY.	REMARKS.
Ends conical, inclined at 30° -	.0018	.56	Franck	..
Ends hemispherical -	.0013	.41	"	...
Ends ellipsoidal, diameter = half major axis	.0012	.38	"	...
Do., diameter = major axis	.0011	.34	"	...
Square prism, end on—plane base -	.0026	.81	"	...
End of prism, pyramids formed of equal triangles	.0018	.56	"	...
Wedge, semi-vertical angle = 70° -	.0028	.9	Eiffel	The ratios $\frac{K^1}{K}$ are those given by M. Eiffel, calculated from K for a flat plate of the same projected area on the wedge. End of cone open. End of cone closed by hemisphere. $R = K^1 \pi r^2 V^2$, where r = radius at greatest diameter.
Do.	.0024	.78	"	
Do.	.0016	.54	"	
Cone, vertical angle 60° -	.0006	.19	"	
Do., point to wind -	.0007	.22	"	
Spindle-shaped body, ratio $\frac{l}{b} = 2$ -	.00024	.073	Renard	...
Do., ratio $\frac{l}{b} = 3$ -	.0001	.032	"	
Do., ratio $\frac{l}{b} = 2$, side to wind -	.0014	.433	"	

Wires.—The resistance of circular wires presents some unusual features. The coefficient K is not a constant, but varies with the product DV , where

D = diameter of wire.

V = velocity.

At higher velocities, however, the variation in K is small, and the resistance of circular wires may be expressed thus :—

$$F_1 = 0.00145 V_1^2.$$

V_1 = velocity in feet per second.

Alternatively the expression is :—

$$F_1 = 0.0031 V^2.$$

Where

V = velocity in miles per hour.

It will be noted that the resistance of wires is practically equal to the same area of flat plate, and the total resistance of the wing is no negligible quantity. In the original B.E.2 machine the resistance of the wires accounted for more than one-third of the head resistance (apart from wing resistance).

It is now customary to use streamline wires of oval section arranged edgewise to the flow of air. These wires present less projected area to the wind than that of the equivalent circular wire, and additionally their resistance coefficient is much less. Streamline wire resistance may be expressed thus :—

$$F_1 = 0.0008 V^2.$$

Where F_1 = resistance in lbs. per square foot of projected area.

And V = velocity in miles per hour.

Effect of Airscrew Draught on Resistance

The air behind the disc swept out by the airscrew is known as the slip stream, and has a velocity relative to the machine about 25 per cent. greater than the surrounding atmosphere. For example, in a machine travelling at 100 m.p.h., the velocity of the slip stream relative to the machine would be about 125 m.p.h. It is evident that the parts of the machine in the slip stream have an increased

resistance, the increase being $\frac{1.25^2}{1} = 1.57$. It is usual in predicting head resistance to calculate as for the velocity of the machine, and then to multiply the resistance of the parts in the slip stream by 1.57.

Wing or Aerodynamic Resistance.—To facilitate a prediction of the lifting capacity and resistance of the wings, experiments have been made with wings of various cross sections, the first experiments being on inclined flat plates.

Pressure on Inclined Flat Surfaces.—The resultant pressure on a flat plate inclined to a current of air is stated by Langley and Dines to be normal to the surface: Stanton and Eiffel came to the conclusion that the resultant pressure made an angle with the normal to the surface of the order of 1° .

The horizontal force on an inclined plane equals the head resistance added to the "drift," or horizontal component of the normal pressure: the vertical force consists of the vertical component of the normal pressure on the plane.

Several determinations of the variation of the pressure on square plates with the angle of inclination have been made, of which the most important results are the following:—

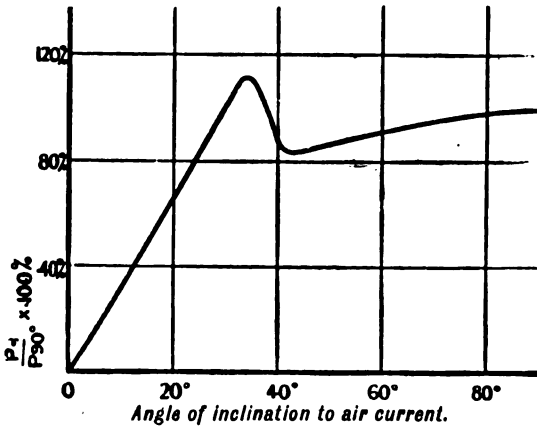
NOTE.— P_α = Normal pressure on plane set at an angle to air current of α° .

P_{90° = Normal pressure on plane set at right angles to air current.

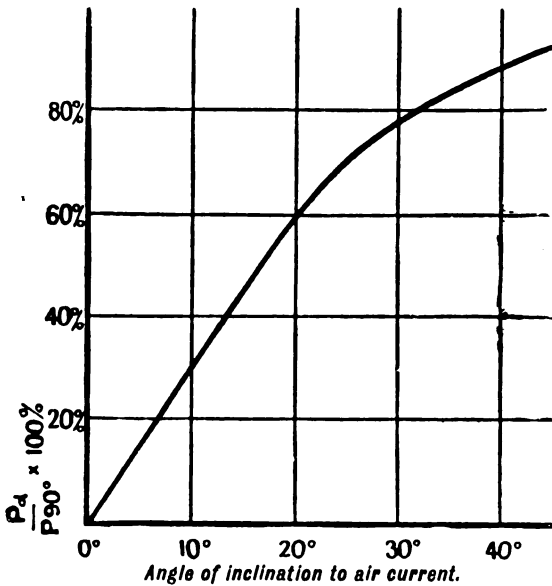
TABLE OF EQUIVALENT INCLINATIONS

Rise.	Angle in Degrees.	Sine of Angle.	Rise.	Angle in Degrees.	Sine of Angle.
1 in 30	1.91	0.0333	1 in 9	6.38	0.1111
1 „ 25	2.29	0.04	1 „ 8	7.18	0.125
1 „ 20	2.87	0.05	1 „ 7	8.22	0.143
1 „ 18	3.18	0.0555	1 „ 6	9.6	0.1667
1 „ 16	3.58	0.0625	1 „ 5	11.53	0.2
1 „ 14	4.09	0.0714	1 „ 4	14.48	0.25
1 „ 12	4.78	0.0833	1 „ 3	19.45	0.3333
1 „ 10	5.73	0.1	...	...	...

533.6.01



Pressure on Inclined Square Plates (Dines).



Pressure on Inclined Square Plates (Langley).

The following formulæ have been proposed, most of them being based upon the experiments of the author of the formula :—

SQUARE PLATES

$\frac{Pa}{P_{90}}$	Becomes for Small Angles.	Authority.	Remarks.
$\frac{2 \sin a}{1 + \sin^2 a}$	$2 \sin a$, or $2 a$	Duchemin	This agrees closely with Langley's experiments.
$2 \sin a - \sin^3 a$	$2 \sin a$, or $2 a$	Renard	Based on Renard's experiments.
$\sin 2 a$, when a is not greater than 45°	$\sin 2 a$, or $2 a$	Institut de Koutchino	Based on experiments of Riabouchinsky.
1, when a is greater than 45°	...	"	" "
a° , when a is not greater than 30°	a° 30	Eiffel	Based on original Eiffel Tower experiments.
a° , when a is not greater than 30°	a° 25	"	Based on M. Eiffel's latest experiments.
$=1$, when a is greater than 30°	.	"	" "
$\sin a$	$\sin a$, or a	Lössl	" "

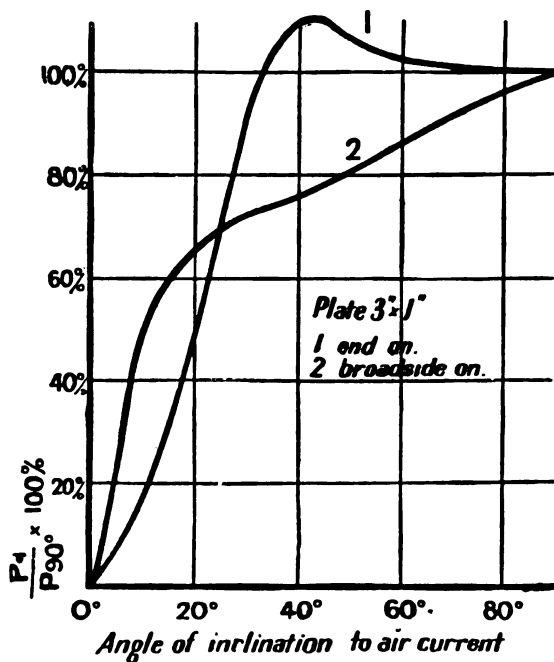
Inclined Circular Disc.—The following results are given by Mannesmann :—

INCLINED RECTANGULAR PLANES 533.6.01

α	15°	23°	30°	37½°	41°	45°
$\frac{P_{\alpha}}{P_{90^{\circ}}}$	·19	·343	·610	·820	·887	·936

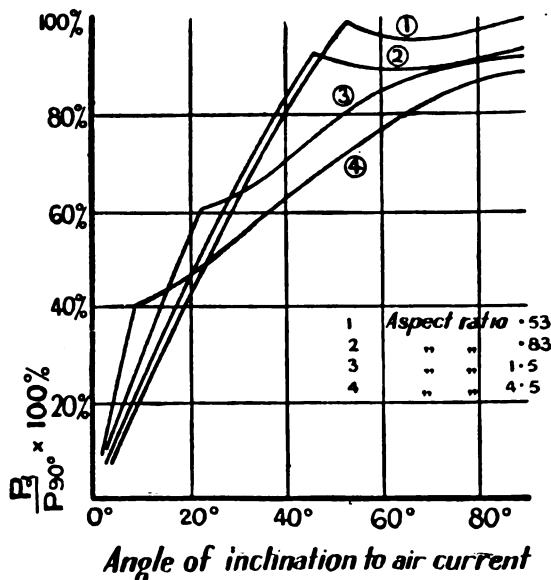
α	60°	67½°	75°	82½°	90°
$\frac{P_{\alpha}}{P_{90^{\circ}}}$	1·002	1·036	1·060	1·029	1·0

Inclined Rectangular Planes.—Stanton experimented on a plate 3 by 1 in., taking readings with the plate both end on and broadside on to the current. His results are given in the curve below. The advantages of a high aspect ratio are clearly shown.



Pressure on Inclined Rectangular Plates (Stanton).

Finzi and Soldati experimented on plates 45 cm. wide and 85, 54, 30, and 10 cm. deep, giving aspect ratios of .53, .83, 1.5, and 4.5 respectively. Their results are given in the curve below.



Pressure on Inclined Rectangular Plates
(Finzi and Soldati).

Soreau has given the following formula for the pressure on rectangular plates inclined to a current of air:—

$$\frac{P_a}{P_{90^\circ}} = \sin \alpha \left[1 + \frac{1 - m \tan \alpha}{(1 + m)^2 + \frac{2m}{1 + m} \tan \alpha + 2 \tan^2 \alpha} \right]$$

Where $m = \frac{l-h}{l+h}$, $2l$ being the horizontal side of the rectangle, and $2h$ the inclined side.

It will be seen that for a square plate this formula reduces to $\frac{P_a}{P_{90^\circ}} = \frac{2 \sin \alpha}{1 + \sin^2 \alpha}$, which is identical with Duchemin's formula.

Distribution of Pressure on Inclined Plates.—Stanton gives the following curves, showing the pressure on the front and the suction on the back of a plate 3 by 1 in. inclined end on to a current of air. The pressures are measured at the median line of the plate.

Plate Inclined at 60°

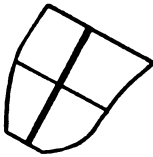
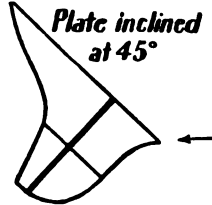


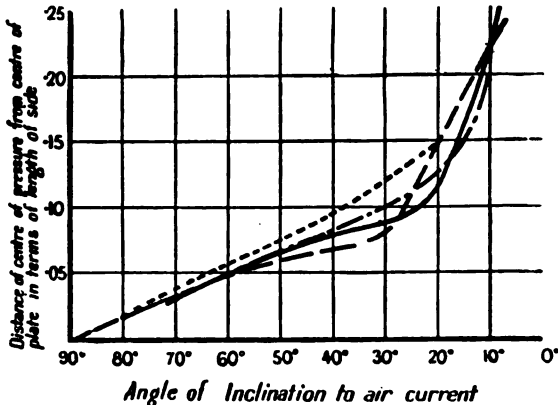
Plate inclined at 30°



Plate inclined at 45°



Centre of Pressure on Inclined Planes.—The most reliable results are shown in the following curves:—



Centre of Pressure on Inclined Plates (Kummer, Langley, Finzi and Soldati, Dines).

The following formulæ have been proposed:—

1. By Joessel, from his experiments on plates immersed in water—

$$x = 0.3[1 - \sin \alpha],$$

Where $x = \frac{\text{distance of C.P. from centre of plate}}{\text{length of inclined side of plate}}$

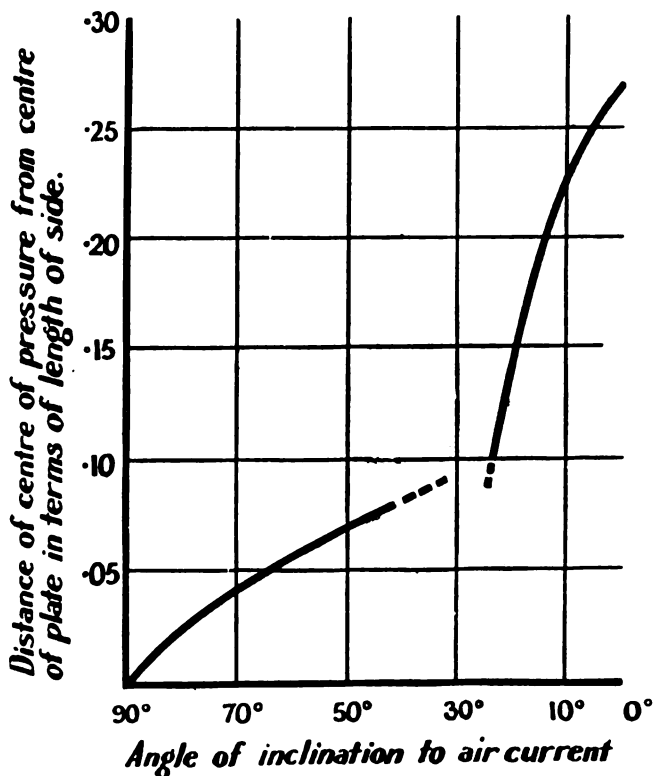
2. By Thiesen—

$$x = 0.2 \frac{\cos \alpha}{1 + \sin \alpha}$$

3. By Soreau—

$$x = \frac{1}{4[1 + 2 \tan \alpha]}$$

This formula of Soreau's agrees very well with the results found by Langley and Dines up to an inclination of 20° , but is probably inaccurate for larger inclinations.



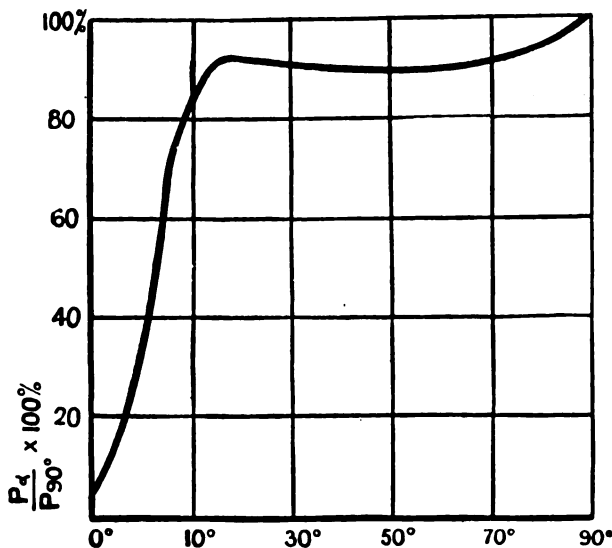
Centre of Pressure on Inclined Plates (Rateau).

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The following table will show to what extent different authorities agree:—

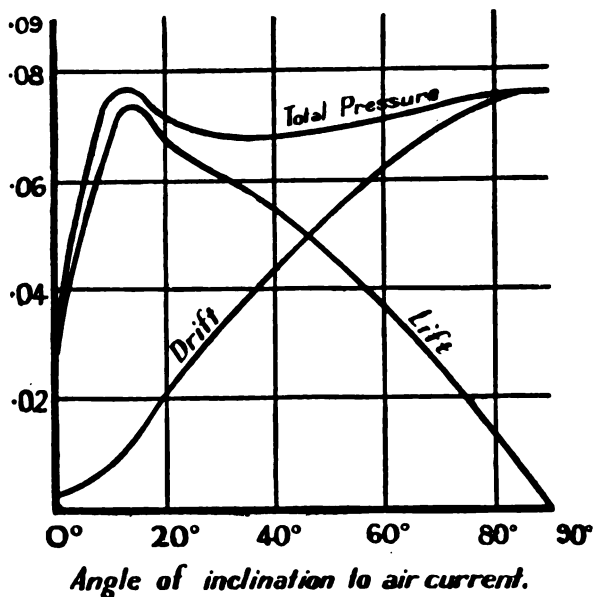
α	Formulae.		Experiments.	
	Joessel.	Soreau.	Dines.	Langley.
10 - -	·247	·185	·200	...
20·5 - -	·197	·143	·125	·146
45 - -	·088	·083	·075	·083
78 - -	·006	·024	·020	·021

Pressure on Inclined Curved Surfaces.—The earliest experiments on this subject were those made by Lilienthal. The camber of his aerofoil was $\frac{1}{12}$; his results are shown in the curve below.



Pressure on an Inclined Aerofoil (Lilienthal).

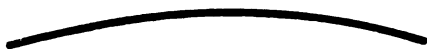
Eiffel experimented with a curved plane of camber $\frac{1}{13.5}$, span 90 cm., chord 15 cm., giving an aspect ratio of 6. The curve below shows his results.



Pressure on an Inclined Aerofoil (Eiffel).

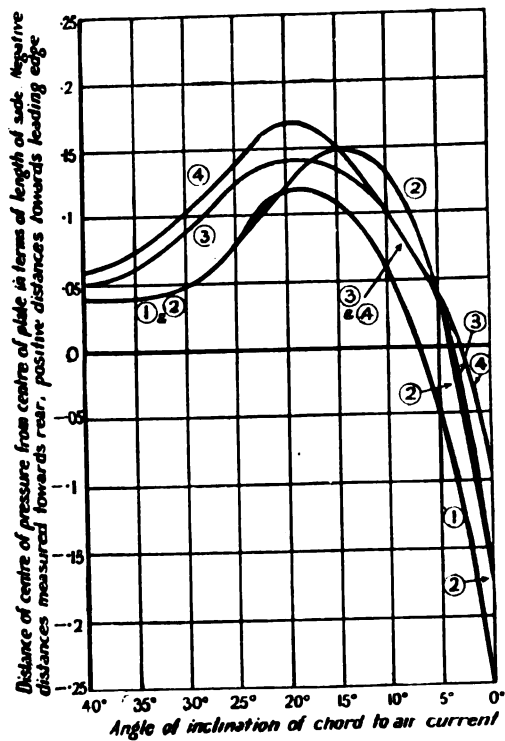
The maximum lift and total pressure both occur when the leading edge of the plane is tangential to the air current.

Centre of Pressure on Curved Surfaces.—Sellers has determined the position of the centre of pressure at varying angles for four different shapes of aerofoil. The aerofoils used were 6 by 12 in.

1 *Circular Arc, Camber $\frac{1}{2}$.*2 *Circular Arc Camber $\frac{1}{4}$.*3 *Aerofoil curved for the front third and flat for remainder Camber $\frac{1}{2}$.*4 *Half vertex of Parabola Camber $\frac{1}{2}$* **Shapes of Aerofoils in Sellers' Experiments.**

No difference was found in the position of the centre of pressure for different velocities of the air current.

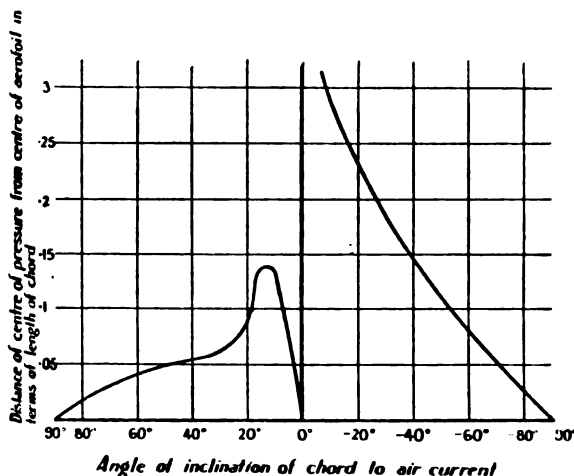
Wilbur Wright has referred in general terms to the movement of the centre of pressure on an aerofoil as follows: "In deeply curved surfaces the centre of pressure at 90° is near the centre of the surface, but moves forward as the angle becomes less, till a certain point is reached varying with the depth of the curvature. After this point is passed the centre of pressure, instead of continuing to move forward with the decreasing angle, turns and moves rapidly towards the rear. These phenomena are due to the fact that at small angles the wind strikes the forward part of the surface on the upper side instead of the lower, and thus this part altogether ceases to lift, instead of being the most effective part of all as in the case of the plane." It will be seen that the above quotation is amplified by Sellers' experiments.



Centre of Pressure on an Inclined Aerofoil (Sellers).

DE-DA (Unobtainable Data System)
 R. Barlow, Matheson, Patents (provisionally protected). U.S. Patent applied for.

The backward movement of the centre of pressure at small angles is also shown, although in a less marked degree, by Eiffel's results, on an aerofoil of circular curvature, camber $\frac{1}{13.5}$, and of dimensions 90 by 15 cm., giving an aspect ratio of 6.



Centre of Pressure on an Inclined Aerofoil (Eiffel).

Thickness of Cambered Planes.—From the structural point of view it is best to have a wing section as deep as is consistent with aerodynamic efficiency. This permits the use of deeper spars with corresponding increase in the factor of safety, or conversely the points of support of the spars may be placed at greater distances apart, resulting in fewer interplane struts, and therefore less head resistance.

Experiments go to show that alterations in the lower surface of a wing do not appreciably alter its aerodynamic properties.

Effect of Alteration of Lower Surface

(National Physical Laboratory)

Tests of a plane with an aspect ratio of 6; camber of upper surface, $\frac{1}{10}$; angle of maximum lift-drift, 4°.

Camber of Lower Surface.	Value of Maximum Lift-Drift.	Value of Lift at Maximum Lift-Drift.	Critical Angle in Degrees.
0	12.8	0.00176	11.5
$\frac{1}{8}\%$	12.9	0.00186	11.25
$\frac{2}{8}\%$	12.3	0.00191	11.75
$\frac{3}{8}\%$	12.8	0.00206	11.75

Alterations in the upper surface of a cambered plane have a marked effect. An increase in camber, or depth of the wing measured from the chord, results generally in—

Decrease in maximum lift-drift ratio.

Increase in maximum lift coefficient.

Higher critical angle or "burble point."

Experimental research has found a satisfactory compromise in a camber of 0.076 chord, this being the maximum camber of the R. A. F. 6 wing section.

Position of Maximum Camber.—The position of the maximum camber relative to the leading edge of the wing has important effects on its aerodynamic properties. A maximum lift-drag ratio is obtained when the maximum camber is situated at one-third of the chord from the leading edge. Here, however, the flow of air at the critical angle is uncertain, which makes it necessary to have the maximum ordinate at three-eighths of the chord from the leading edge, where the flow at the critical angle is steadier.

Aspect Ratio.—The ratio of span to chord has important bearings on wing efficiency. Model experiments are now usually conducted on models 18 in. $\times$ 3 in., i.e., aspect ratio 6 at a wind speed of 40 ft. per second in the tunnel. To correct the results obtained from such experiments, so as to make them applicable to other aspect ratios, the various coefficients and lift-drag ratios may be multiplied by the factors in the following table, deduced from N.P.L. experiments.

Scale Effect.—When making use of results of model experiments to predict the properties of a full size wing, attention must be paid to the difference in size or scale, as it has been shown that the various coefficients vary with the product of linear dimension and velocity. At the usual velocities of flight and sizes of wings the variation in the coefficients is small, so that certain multiplying factors can be applied to the result of model experiments to make them applicable to full size wings.

CORRECTING FACTORS

533.65.01

MULTIPLYING FACTORS TO CORRECT FOR ASPECT RATIO

Angle of Incidence.	Aspect Ratio.											
	8		7		6		5		4		3	
	$\frac{K_y}{K_x}$	K_y	$\frac{K_y}{K_x}$	K_y	$\frac{K_y}{K_x}$	K_y	$\frac{K_y}{K_x}$	K_y	$\frac{K_y}{K_x}$	K_y	$\frac{K_y}{K_x}$	K_y
-2	.56	.64	.22	.27	1.0	1.0	1.33	1.18	1.33	1.25	1.28	1.25
0	1.17	1.17	1.0	1.07	1.0	1.0	1.05	1.00	1.28	1.29	.96	1.03
2	1.04	1.05	1.04	1.04	1.0	1.0	.95	.94	.89	1.01	.72	.82
4	1.03	1.04	1.05	1.04	1.0	1.0	.91	.98	.83	1.00	.70	.85
6	1.16	1.07	1.11	.99	1.0	1.0	.93	.95	.83	1.00	.75	.86
8	1.15	1.04	1.07	.96	1.0	1.0	.90	.92	.82	.95	.73	.83
10	1.15	1.08	1.10	.96	1.0	1.0	.92	.96	.83	.90	.78	.83
12	1.15	1.04	1.09	.98	1.0	1.0	.93	.97	.80	.89	.74	.84
14	1.10	1.00	1.04	.98	1.0	1.0	.93	.96	.84	.89	.72	.83
16	.99	1.00	1.03	.99	1.0	1.0	.99	1.00	.85	.98	.77	.90
18	.98	.98	.95	1.00	1.0	1.0	1.01	.97	1.03	1.00	1.01	.97

In the above table K_y = Lift
 K_x = Drift
 K_y = Lift coefficient.

MULTIPLYING FACTORS TO CORRECT RESULTS OF MODEL EXPERIMENTS AT 40 FT. PER SECOND TO MAKE THEM APPLICABLE TO FULL SIZE WINGS

Angle of Incidence.	$\frac{K_y}{K_x}$	K_y
-1	1.60	1.28
0	1.35	1.10
2	1.17	1.06
4	1.10	.99
6	1.08	.99
8	1.06	.99
10	1.04	.99
12	1.04	.99
14	1.04	.99
16	1.02	.99

CORRECTIONS FOR BIPLANE ARRANGEMENT OF WINGS

Ratio Gap:Chord.	Multiplying Factor for Lift Coefficient.			Multiplying Factor for Lift-Drift Ratio.		
	6°.	8°.	10°.	6°.	8°.	10°.
0·4	0·61	0·62	0·63	0·75	0·81	0·84
0·8	0·76	0·77	0·78	0·79	0·82	0·86
1·0	0·81	0·82	0·82	0·81	0·84	0·87
1·2	0·86	0·86	0·87	0·84	0·85	0·88
1·6	0·89	0·89	0·90	0·88	0·89	0·91

R.A.F.6 WING

Angle of Inclination of Chord.	Lift Coefficient (Absolute).	Drift Coefficient (Absolute).	Lift-Drift Ratio.	Centre of Pressure Coefficient.
- 2	0·003	0·0201	...	
0	0·074	0·0165	4·5	0·575
2	0·173	0·0159	10·9	0·425
4	0·275	0·0193	14·3	0·358
6	0·354	0·0252	14·1	0·329
8	0·423	0·0329	12·9	0·312
10	0·496	0·0433	11·4	0·302
12	0·564	0·0545	10·4	0·292
14	0·593	0·0640	9·3	0·280
16	0·605	0·0875	6·9	0·296
18	0·550	0·1336	4·1	0·330
20	0·500	0·1665	3·0	0·365
22	0·476	0·1845	2·6	0·385
24	0·456	0·2015	2·3	0·400

$$D = K_p V^2,$$

Where D = drift in lbs. per square foot.

PDF-DA (Detachable Data) System
R. Bruce Matheson Patents (personally protected), U.S. Patents applied for

The efficiency of biplane arrangements is increased by staggering the bottom plane behind the upper. When the leading edge of the lower plane is about two-fifths of the chord behind the leading edge of the upper, both the lift coefficients and lift-drift ratios are improved 5 per cent.

Note Regarding the above Correcting Factors

When applying the above correcting factors to a model, all the appropriate factors must be used. For instance, for a biplane of aspect ratio 7, the results of the monoplane model must be multiplied by the factor for scale effect, the factor for aspect ratio, and the factor for biplane effect.

Modern Wings.—The R. A. F. 6 wing section may well be selected as an example, for it has been widely used, and is amongst the most efficient of wing sections. This was the wing section for the B.E. 2C aeroplane. It is a medium lift wing. Its aerodynamic properties, as given by a model of aspect ratio 6, tested at 30 ft. per second wind speed, are as shown in Table on previous page.

HORSE-POWER TO MOVE A PLANE SURFACE.

Where H.P. = horse-power, S = area in square feet,
and v_1 = velocity in feet per minute,

$$H.P. = 0.000,000,000,010 S v_1^3.$$

Speed in		H.P. per Square Foot of Effective Surface.
Miles per Hour.	Feet per Minute.	
$\frac{\text{ft.p.m.} \times 60}{5,280}$	$\frac{\text{m.p.h.} \times 5,280}{60}$	
10	880	0.0068
15	1,320	0.0230
20	1,760	0.0546
25	2,200	0.1065
30	2,640	0.1841
50	4,400	0.8560
75	6,600	2.874
100	8,800	6.810
150	13,200	23.000
200	17,600	54.600

STRUCTURAL DESIGN AS APPLIED TO AEROPLANES

533.65

General engineering practice concerning theories of structures and strength of materials can be applied with equal effect to

determine the stresses in, and hence the dimensions of, the various parts of an aircraft. These are, of course, based on assumption of the magnitude and conditions of loading under various states of flight and rest.

The general lay-out of an aeroplane, such as wing area, span and chord, tail area, etc., are predetermined by aerodynamic considerations. These considerations naturally depend upon the speeds required and the total weight of the machine. These initial estimates must be made from experience supported by calculation.

It is usual to construct a wing with two spars, one about one-sixth of the chord and the other about two-thirds of the chord, from the leading edge. For normal angles of incidence the centre of pressure on the wings lies between the two spars. However, the centre of pressure moves relatively to the leading edge at different angles of incidence, and depends on the form of wing section adopted. It is evident, therefore, that it will sometimes be nearer the front spar, and sometimes closer to the rear. Having fixed on the wing section from considerations of the performance required, the movement of the C.P. with the incidence is known, and each spar must be designed with due regard to this travel.

For instance, assume that the wing section adopted gives the best flying angle (maximum lift/drag) at 5° , and the position of C.P. for this angle at 0.3 of the chord from the leading edge. The C.P. will move backward for smaller angles, and forward as the incidence increases. The angle giving highest velocity may be 2° with the 0.43 from the leading edge, and at the maximum of 15° , 0.27. Then, as the reaction is taken as acting through the C.P., the load taken by each spar may be determined by the application of the principle of three moments. Thus the load per foot-run for each spar is calculated, and a bending moment diagram can be prepared. For purposes of calculation the ribs may be considered as beams with evenly distributed load, and supported at two points, i.e., the main spars. The latter are, in addition to bending, subjected to direct tension or compression due to lift, and also direct tension or compression due to drift. All these factors must be considered in determining the dimensions, position of spindling, etc. With regard to calculations for the planes, it should be pointed out that the weight of the planes themselves should be deducted from the total weight in determining the weight per unit area.

The fuselage is considered as a beam supported at the main and tail plane attachments when in the air, and at the undercarriage and tail skid attachments when the machine is on the ground. The weights to be considered are the pilot, engine, petrol tanks, etc., when the machine is on the ground, and when in the air the weight of the undercarriage must also be included. For any member the condition which gives the heavier stresses must be followed in deciding the section. As regards the undercarriage, it is experience

and experiment which to a large extent govern design, for the stresses set up by violent landings are almost indeterminable.

Several approximate methods of calculations have been evolved for aeroplane work, such as in N.P.L. Report, No. 83, for 1912-13 (Bairstow and MacLachlan). Graphic solutions often save much time, and Ritter's method is specially worthy of attention in this connection. This system is described by Mr E. O. Williams in *Flight* of 30th November 1916.

WEIGHTS OF PARTS OF AN AEROPLANE FOR PRELIMINARY ESTIMATES

(For *Weights of Engines, Fuels, etc.*, refer also to Division 621.431).

PART.	WEIGHT.
Engine	- If exact weight not available assume :—
	1. Air cooled - 4 lbs. per H.P. up to 100 H.P.
	„ - 3.5 lbs. per H.P. between 100 and 200 H.P.
	2. Water cooled with radiator 4.25 lbs. per H.P. up to 100 H.P.
	Without radiator 3.5 lbs. per H.P. between 100 and 200 H.P.
	Radiators for - 0.75 lb. per H.P.
	Cooling water - 0.35 „ „
Engine Mounting	- One-seventh weight of rotary engine.
	One-tenth „ fixed „
Engine Cowling	- $2\sqrt{\text{weight of engine}}$ lbs. for rotary engine.
	$\sqrt{\text{weight of engine}}$ „ fixed „
Fuel	- Petrol—air cooled 0.65 lb. per B.H.P. hour.
	fixed
	Petrol—aircooled 0.70 lb. per B.H.P. hour.
	rotary
	Petrol—water 0.50 lb. per B.H.P. hour.
	cooled
	Oil—air cooled 0.10 lb. per B.H.P. hour.
	fixed
	Oil—air cooled 0.25 lb. per B.H.P. hour.
	rotary
	Oil—water cooled 0.05 lb. per B.H.P. hour.
Fuel Tanks	- One-fifth weight of contents, 1 to 1½ lbs. per gallon, according to shape.

WEIGHTS OF PARTS OF AN AEROPLANE—*Contd.*

PART.	WEIGHT.
Aircrew . . .	3√horse-power in lbs.
Main Planes . . .	From .75 up to 1.25 lbs. per square foot of wing surface.
Tail Unit . . .	.5 to .75 lb. per square foot of entire area of tail plane, elevators, rudder, and fin.
Fuselage . . .	Considerable variation, say 60 to 200 lbs., according to type of machine.
Undercarriage . . .	About one-fourteenth of total weight.
Pilot . . .	160 to 180 lbs. (military specification, 180 lbs.).
Seating Pilot . . .	10 lbs.
Controls . . .	Considerable variation according to type, say 30 to 50 lbs.
Instruments . . .	20 lbs.
Wireless Equipment . . .	100 lbs.
Self-Starter . . .	Compressed air, 55 lbs. for 150 H.P. engine. Auxiliary petrol engine, 60 lbs. for 150 H.P. engine.
Gun and Ammunition . . .	Approximately 150 lbs., but may vary considerably.
Useful Load Carried . . .	0.25 to 0.40 of the total weight of the aeroplane.

For an actual machine of about 130 H.P., carrying 475 lbs. of military load and fuel for five hours; capable of a slow speed of 45 M.P.H.; with a factor of safety on the main planes of seven to eight; and with a gross weight of 2,400 lbs.; the following is the weight percentage of the different components of the complete system :—

	Percentage of Total Gross Weight.
1. Aeroplane, without power plant, fuel, or military load, but including main planes, fuselage, fuel tanks, chassis, control, auxiliary surfaces, etc.	31
2. Power plant, 130 H.P., including motor complete (without fuel), with radiator, water, airscrew, etc.	31
3. Military load, including pilot, observer, instruments, machine guns, ammunition, bombs and racks, radio-telegraphic set, camera, etc.	19.5
4. Fuel load, petrol and oil for five hours at full power	18.5
	100.0

WEIGHT OF COMPONENTS OF A BIPLANE

A Two-seater, with 340 sq. ft. main plane area

(A. W. Judge)

A. DEAD LOADS.	Weight in Lbs.
70 H.P. engine complete -	410
Tanks (for oil and 40 gals. petrol) -	40
Upper wing -	100
Lower wing -	85
Control surfaces -	35
Fuselage, complete -	140
Landing chassis and tail skid -	80
Propeller, complete -	17
52 strainers -	6
240 ft. cable -	14
80 ft. struts -	56
Clips, fittings, wire, and bolts -	25
Total dead load -	1,008
B. LIVE LOADS.	
Petrol for six hours -	240
Oil -	20
Pilot and "passenger" -	320
Total live load -	580
Total weight -	1,588

MODERN AEROPLANES

Average Distributions

	Per Cent. of Aeroplane Parts.	Resist- ance.	Per Cent. of Total Weight.
Main planes - - - -	41	15	13
Fuselage - - - -	41	62	13
Tail unit - - - -	6	7	2
Undercarriage - - - -	12	16	4
	<u>100</u>	<u>100</u>	
Engine unit (including tanks, etc.) -	...	...	53
Useful load - - - -	...	...	15
			<u>100</u>

WEIGHT OF COMPONENTS OF AN L.V.G. (GERMAN) BIPLANE

A two-seater with 405 sq. ft. main plane area

A. DEAD LOADS.		Lbs.	Lbs.
Main planes, complete	- -	375	
Fuselage	- -	714	
Engine unit (170 H.P.)	- -	732	
Airscrew	- -	42	
Total weight, empty	- -	—	1,863
B. LIVE LOADS.			
Fuel and oil	- -	430	
Crew (2) and armament	- -	551	
Total weight, live loads	- -	—	981
Total of dead and live loads	- -	-	<u>2,844</u>
Weight per sq. ft.	- -	7 lbs.	
„ H.P.	- -	17 lbs.	

Number of Parts in an Aeroplane

Exclusive of the engine, the following parts are used in the construction of a simple type of American aeroplane:—

Spruce	- -	244 ft.	Varnish	- -	11 gals.
Pine	- -	58 ft.	Aluminium	- -	65 lbs.
Ash	- -	31 ft.	Forgings	- -	798 total.
Hickory	- -	1 ft.	Steel stampings	- -	921 total.
Rubber	- -	34 ft.	Turnbuckles	- -	276 total.
Ply wood	- -	57 sq. ft.	Screws	- -	3,377 total.
Fabric	- -	201 sq. yds.	Nails	- -	4,326 total.
Dope	- -	59 gals.	Wire	- -	3,262 ft.

In a modern aeroplane there are 3,000 to 4,000 parts (without counting screws and nails), usually made up into about 250 components.

*DE-DA (Detachable Data) System
R. Burdette Matthews' Patents (provisionally protected). U.S. Patents applied for.*

AEROPLANE DESIGN

The General Design—Longitudinal Stability—Directional Stability—Lateral Stability—Elevators—Lateral Control—Soaring—Standard Wing Sections—Undercarriage—Parachutes—Structural Design—Definitions of Terms—Design Details—Weights of Components of an Aeroplane—Jigs and Fixtures—Disposition of Factory Accommodation—The Newall Standard Tables of Limits—Space required for Aeroplane Manufacture.

THE design of an aeroplane may be divided into three distinct series of calculations:—

1. Stability calculations, which determine the correct relative areas of wings, tails, elevators, rudders, and fins, to ensure an inherent tendency of the machine to right itself under all conditions of flight. It is also necessary to determine the centre of gravity of the machine.

2. Predictions of the performance before the machine is built, such as maximum and minimum speeds, rate of climb, maximum altitude attainable, etc. These calculations are based on results of model experiments on the air resistance of the various parts of a machine as given in Division I.

3. Calculations concerning the necessary strength of the various parts of the aeroplane to withstand any stresses to which it may be subjected. This part of aeroplane calculation is dealt with a little later on.

Specifications.—The skeleton specification from which a modern designer commences his task, always gives details of the loads to be carried, and the performance that must be given. In the case of a single-seater tractor scout (fighter or pursuit) aeroplane, the following may be taken as typical, though, perhaps, not fully illustrative of the latest practice:—

	Lbs.
Loads—PILOT	180
2 synchronised guns firing through the	
airscrew, plus 750 rounds of	
ammunition	140
Gun sights	8
Oxygen apparatus	15
Miscellaneous loads	107
	150
Total	350 to 500

Also fuel and oil for $\frac{1}{2}$ an hour at ground level $\times$ plus $2\frac{1}{2}$ hours at 15,000 ft. at full speed.

Performance.—Speed not less than 130 m.p.h. at 15,000 feet. Landing speed, not more than 50 m.p.h. Climb to 20,000 ft., not more than 22 min. Climb, from 10,000 to 20,000 ft. in 10 min. Service ceiling (climb=100 ft. per min.), 25,000 ft.

General Details.—The equipment should provide for electrically heated clothing and guns; wireless telephone; self-sealing tanks; carriage of about 80 lbs. of bombs and gear, in emergency.

Especially good climbing capacity is of great importance, as is also visibility and handiness in manoeuvring.

A Two-seater Fighter or Reconnaissance Aeroplane should have a performance of 120 m.p.h. at 15,000 ft., and climb to 20,000 ft. in 25 min., with a service ceiling of 25,000 ft. The endurance at full speed should be $\frac{1}{2}$ an hour at the ground and 3 hours at 15,000 ft. The total load to be provided for should be 700-800 lbs. (exclusive of fuel and water).

A Night Bomber should have a performance of 90-100 m.p.h. at ground, and climb to 10,000 ft. in 30 min., with a service ceiling of 12,000 ft. The endurance at 10,000 ft. should be 9 hours. The total load to be allowed for is usually about 1,500 lbs. on the smaller aeroplanes (exclusive of fuel, water, and 600 lbs. of bombs). On the larger bombers the load is usually 2,000 lbs., plus fuel, water, and anything over 2 tons of bombs.

General Design.—The design of the earlier aeroplanes was largely a process of trial and error; this is only partly true to-day. Specifications are very complete, and designers start with a very good idea of weights and proved data relative to aerodynamics.

The modern aeroplane consists of a main plane or its equivalent biplane form, which flies at an angle to the relative wind. A tail plane, including the elevators, flies normally at a small angle or in the air stream. In the latter case it merely acts as a stabiliser, not carrying any load unless disturbed from its normal position.

The main plane and the tail plane are connected by a rigid structure called the fuselage. The whole is mounted on a frame known as the landing chassis, and carrying freely running light wheels, which enable it to travel on the ground. An engine rotating an airscrew is fitted into the main structure. This engine exerts a thrust *B*, urging the machine forward. When the engine is started, the machine, if not anchored or held back, commences to move along the ground. It then increases its rate of motion until it has attained its minimum flying speed.

For every wing section there is a certain maximum lift coefficient, and in the majority of wing sections it is only exerted when the angle of incidence of the wing is in the neighbourhood of 16° to 18° .

The exact magnitude of the maximum lift coefficient, and the angle at which it occurs, is determined by experiments on model wing sections.

As explained in 533.6.01, the force exerted per unit area of wing is found by multiplying the lift coefficient by the square

of the speed in miles per hour. For a particular machine of known weight, the wing loading equals the total weight divided by the wing area. It is evident that the machine will not lift until the force exerted by the relative wind on the wing equals the wing loading.

If K is the maximum lift coefficient of the wing,

V is velocity in miles per hour,

W is total weight of machine in lbs.,

A is area of main surface in square feet,

Then $\frac{W}{A}$ lbs. per square foot is the wing loading, and KV^2 lbs. per square foot is the force exerted by the relative wind on the wing.

For the machine to fly

$$\frac{W}{A} = KV^2.$$

To satisfy this equation, V can have only one value, and equals

$$\sqrt{\frac{W}{K}} \text{ miles per hour.}$$

In actual design the converse of the problem is given. A certain landing speed is specified, and from this the wing loading is determined, and hence the area of the wings to support estimated weight of the machine.

Four forces act on an aeroplane in flight :—

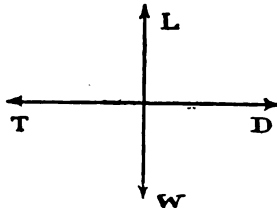
W = Total weight acting vertically down through the C.G.

L = Total lift acting vertically upward through the C.G.

T = Thrust due to the airscrew acting along the centre line of thrust.

D = Drag or resistance total acting through the centre of resistance.

The simplest possible arrangement is as follows :—



Such seldom occurs, and could not be maintained for various reasons which are obvious, if carefully thought out.

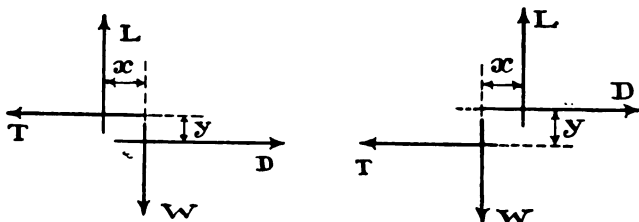
The position and magnitude of L is variable with different angles of incidence of the plane.

T is variable in magnitude, owing to difference of speed of engine, and during glide is zero.

D also is variable in magnitude.

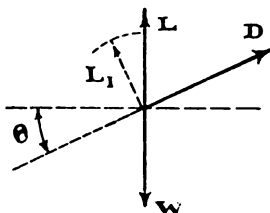
W is variable also, because modern aeroplanes have to be stable with different loads, *e.g.*, bombers.

The next two figures show the relative position of the varying forces.



The weight-lift couple must be equal to the thrust-drag couple, *i.e.*,

$$W \times X = T \times Y.$$



During gliding, **T** is zero. **D** is dynamic. **L**, lift at gliding angle. **L₁**, direct vertical component of **L**, θ = gliding angle.

For instance, a usual landing speed is 45 m.p.h., and a good average maximum lift coefficient for an efficient wing section is 0.0027. The wind force on the wing at 16° incidence equals $0.0027 \times 45^2 = 5.5$ lbs. per square foot. If the estimated weight of the machine were 2,000 lbs., the wing surface required would be $2,000 \div 5.5$ sq. ft. = 365 sq. ft., *e.g.*, this would be provided by two wings

having a chord and a span of 5 ft. and 36 ft. 6 in. respectively.

It will therefore be observed that the machine travels or "taxies" over the ground until its minimum flying speed is exceeded, when it is able to rise. The forces acting on the machine when flying horizontally may be resolved into four kinds as enumerated above.

Longitudinal Stability.—An aeroplane is commonly said to have longitudinal stability when it has an innate tendency to maintain a constant attitude to its flight path. More scientifically, where it is separable from lateral stability, this term is expressed as the stability of the motion of an aeroplane in the plane of symmetry, or stability with reference to the lateral axis. A cambered surface, such as is employed in the construction of an aeroplane wing, is longitudinally unstable at those angles of incidence (below 15°) which give a suitable lift-drift ratio. At the normal angle of incidence the centre of pressure (C.P.) of the machine coincides with the centre of gravity (C.G.). However, with a slight disturbance, the centre of pressure (C.P.) will move either forward or back of the centre of gravity, and therefore has to be corrected. To counteract this unstabilising effect, a tail or rear stabilising plane is usually fitted. This tail is generally so set as to have either (a) no angle of incidence, or (b) a lesser angle than the normal angle of the main planes. This lesser angle (when adopted) does not usually exceed one-third that of the main surface. When the centre of pressure (C.P.) moves, say, forward, owing to the movement of the main surface out of the normal position, the tail, instead of having practically no angle of attack and no lift, is swung out of its normal position, and thus exercises a lift, and so restores the whole machine to its original position. Of course this operation naturally necessitates a greater or lesser change in the altitude, which is immaterial at ordinary flying heights.

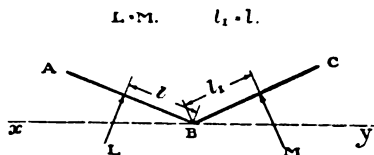
Directional Stability.—When an aeroplane encounters a gust at an angle to itself (in plan view), it yaws more or less. If the resultant side force, on all the surfaces exposed to a side wind, acts at a point in front of the centre of gravity (C.G.) of the machine, it will be turned at right angles to the gust, and an aeroplane with this characteristic is called directionally unstable. To make the machine stable the area of the rudder and the fin is adjusted, so that under all conditions the centre of side pressure is at or behind the centre of gravity (C.G.) of the machine. By varying the angle of the rudder, the balance of side forces is disturbed, and the machine can thereby be caused to deviate from the straight path.

Another reason for using a vertical fin is to enable the machine to recover from a "side-slip." If the aeroplane commences to slide sideways through the air, some means of bringing the tail up and the front down must be provided, so as to convert the side-slip into a "nose-dive," and permit the pilot to regain control. If a vertical surface is provided aft of the centre of pressure on the planes, this will result automatically, and, provided the machine was at a sufficient height at the beginning of the slip, it will regain its natural gliding position.

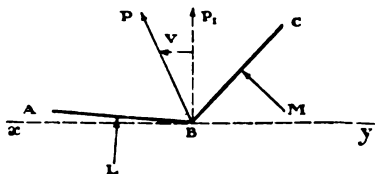
Lateral Stability is the stability of an aeroplane about its longitudinal axis, that is non-rolling. This term may, perhaps, be more

precisely expressed by defining it as the stability of the motion of an aeroplane out of the plane of symmetry, i.e., of side-slipping, rolling, and yawing. It is not so easy to correct as longitudinal or directional stability, since the tendency to rotate takes place about an axis which is parallel, or nearly so, to the path of flight. A certain amount of lateral stability can be obtained by inclining the planes on each side of the machine at a slight dihedral angle, as indicated in the illustrations herewith.

The normal position of the aeroplane wings is such that angles $ABx-CBy$ are equal.



When machine heels over one angle becomes greater than the other, as in the following diagram :—



The pressure on the surface is always at right angles to the respective planes.

The resultant lift BP is (on account of the new position of the wing) no longer vertical.

The vertical lift becomes P_1 , and the force acting along the lower wing is represented by V.

This may be solved graphically.

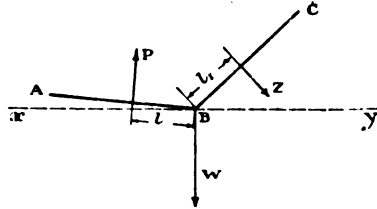
The result is side-slip in the direction of wing with least inclination.

The wings now act laterally in the same manner as forward, and have a C.P. which can be determined.

The normal C.P.'s for straight flights are L and M respectively, and are located approximately at centre of plane.

Owing to flow of air diagonally C.P. will probably be nearer B, and this will also act at right angles to the plane, the wing tip A being the leading edge.

The C.G. remains the same, and is indicated by W.



This condition introduces a couple acting on plane BC, and restoring equilibrium.

Stability by Longitudinal Dihedral Angle

The sketch shows an exaggerated condition in order to add clearness to the figure.

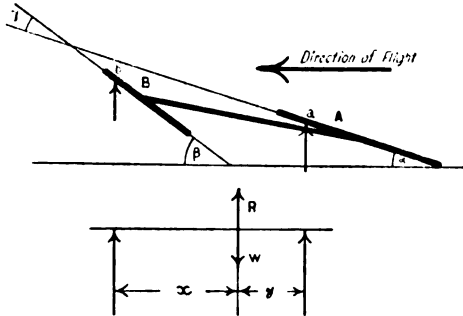
Total pressures are proportional to A and B.

Resultant pressure = $R = Aa + B\beta$, and acts at a point such that—

$$\frac{y}{x} = \frac{B\beta}{Aa} = \frac{B(a + \gamma)}{Aa} = \frac{B}{A} \left[1 + \frac{\gamma}{a} \right].$$

Now let us suppose that the aeroplane pitches, so that a and β are reduced.

Then $\frac{\gamma}{a}$ will be increased, i.e., $\frac{y}{x}$ is increased.



- a. Angle of incidence of rear plane (A).
- β . " " leading plane (B).
- a. Centre of pressure on rear plane (A).
- β . " " leading plane (B).
- γ . Angle between leading and rear planes.

Since α and β are small, the pressures per square foot are proportional to α and β .

This will mean that the resultant pressure moves forward, producing a righting effect on the machine considered as a whole. The same argument may be applied if the effect of a backward "pitch" of the aeroplane is considered.

The above proof is due to Mr T. W. K. Clarke.

The foregoing pages illustrate generally the principles upon which stability depends, and though every machine must be constructed on lines which enable these principles to be adopted, the merely automatic adjustment resulting has to be supplemented by manipulation on the part of the aviator. To maintain equilibrium under the ever-changing wind conditions, it is advisable that the relative inclination of the main planes should be capable of variation. Means are accordingly provided for altering the angles of the right and left hand planes relatively to each other. In some machines this is effected by making part of the planes flexible, and simultaneously warping or bending this part upwards on one side of the machine and downwards on the other. In other cases supplementary planes on opposite sides of the machine are employed, one being inclined upwards while the other is simultaneously inclined downwards. In either case the result is in effect to alter the relative angles of the right and left planes, so as to maintain stability under all conditions which may arise.

In the design of a machine too much inherent stability must be avoided, or it will not be so controllable from the pilot's point of view. If the inherent stability of an aeroplane is too high, it will tend to follow alterations in wind direction, which makes it uncomfortable to fly, and dangerous in landing.

Soaring.—The question of "soaring" was brought into prominence by the experiments of the Wright Brothers.

"Soaring" has been defined as "gliding in an upward current of air," i.e., a current such that the natural downward fall of a glider is counteracted by the upward trend of the wind. It has long been known to be possible, and it may be taken that the following are the requisites for its performance:—

1. Perfect control of the aeroplane.
2. A very low gliding angle, obtained by diminution of head resistance. The gliding angle must probably be reduced to at least 5° or 4° .
3. A suitable locality for practice.
4. An initial forward velocity is necessary before soaring can be commenced.
5. It is probable that when actually soaring the angle of incidence of the machine will be *negative* and not less than 3° .

It will be noticed that once a sufficient altitude has been obtained, progress may be made in any desired direction by gliding downwards.

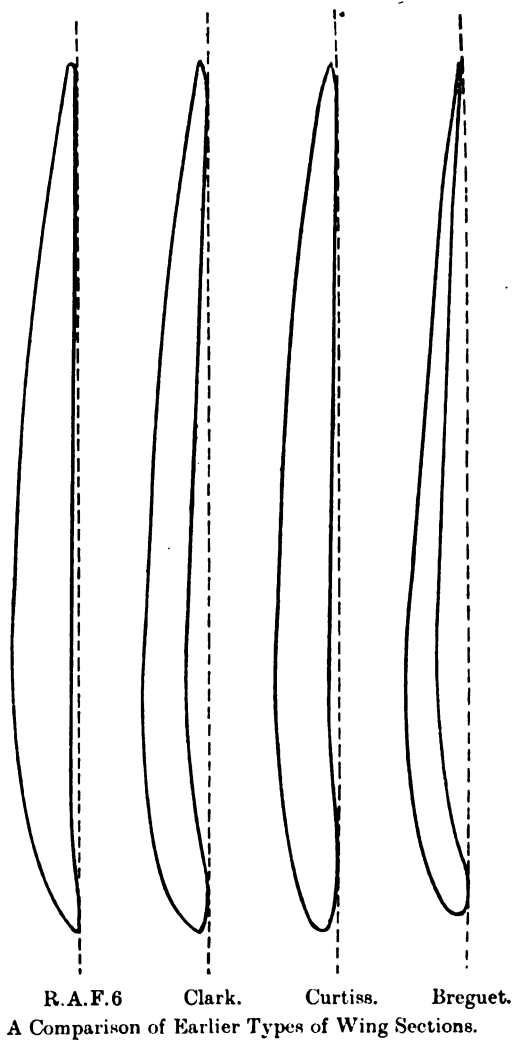
Elevators.—For any particular angle of incidence of the main wings there is only one possible speed for horizontal flight speed. If the engine throttle were opened farther than necessary for this horizontal speed, there would be no increase in the speed; otherwise the force on the wings would be greater, and the lift would not balance the weight. The normal result of the opening of the throttle results in the climbing of the machine. To alter the horizontal speed, the angle of incidence of the main wings must be varied. This is done by adjusting the angle of the elevators, which adjustment alters the longitudinal balance of the machine, resulting in a new position of equilibrium, with the wings at a new angle of incidence.

Thus it is seen the elevators do not directly elevate the machine, and to that extent the name is a misnomer.

If, when the wings are at a certain angle, the thrust horse-power required is H_1 , and on altering the elevators and the angle of incidence the thrust horse-power required is reduced to H_2 , then, unless the throttle is adjusted, the horse-power $H_1 - H_2$ is available for climbing.

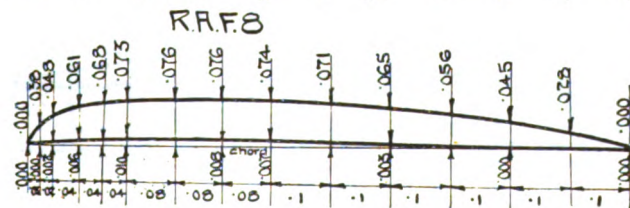
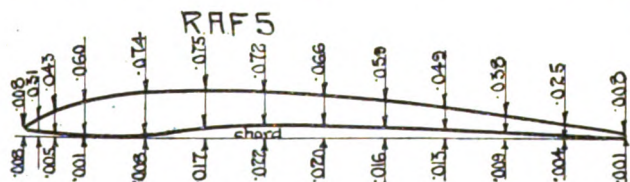
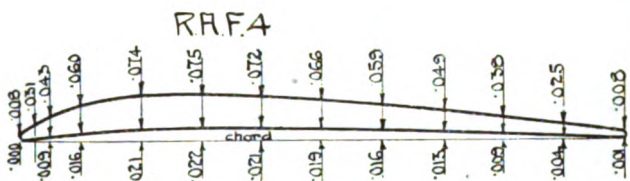
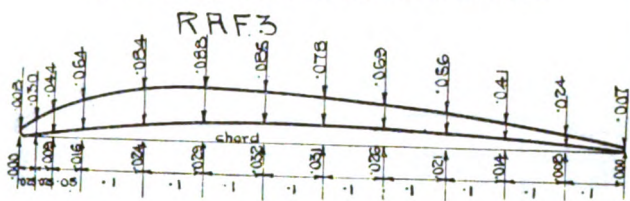
DIMENSIONS OF STANDARD WING SECTIONS

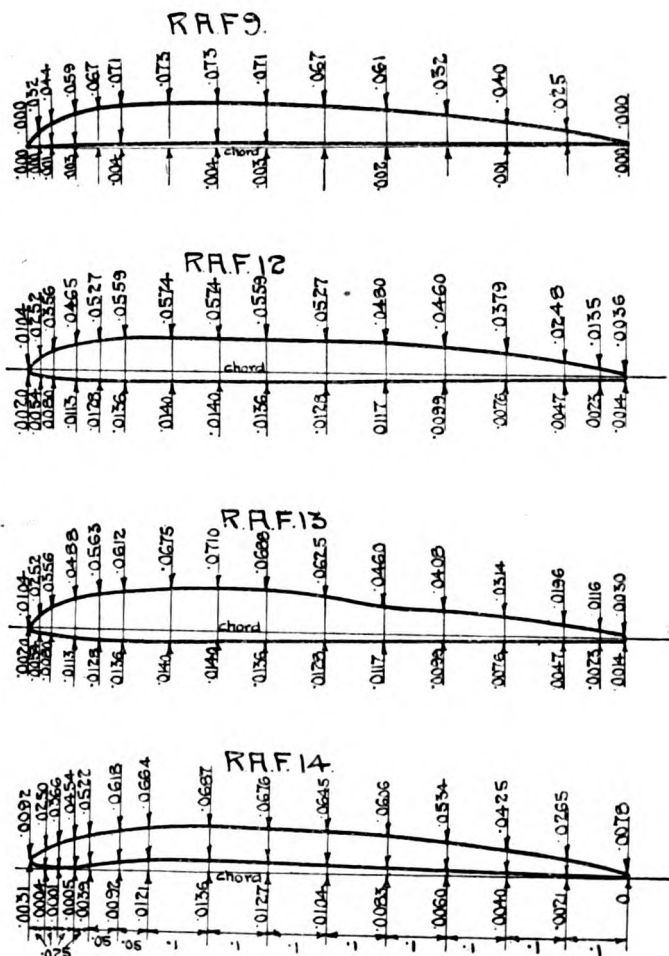
Distance from Leading Edge in Fraction of Chord.	Height above Chord in Fraction of Chord.							
	R.A.F.6		Clark.		Curtiss.		Breguet.	
	Upper Surface	Lower Surface	Upper Surface	Lower Surface	Upper Surface	Lower Surface	Upper Surface	Lower Surface
0	0.005	0	0.01	0.008	0.016	0.016	0.016	0.016
0.25	0.032	...	0.037	0.005	0.038	...	...	...
0.5	0.044	0.002	0.048	0	0.045	0.001	...	...
0.1	0.060	0.004	0.063	0.007	0.052	0.005	...	...
0.2	0.074	0.007	0.078	0.022	0.066	0.009	0.041	0.087
0.3	0.076	0.008	0.075	0.027	0.068	0.010	...	...
0.4	0.075	0.007	0.071	0.023	0.068	0.011	0.041	0.076
0.5	0.071	0.005	0.065	0.018	0.066	0.010	...	...
0.6	0.065	0.004	0.055	0.013	0.060	0.008	0.038	0.069
0.7	0.057	0.003	0.047	0.005	0.053	0.004	...	...
0.8	0.044	0.002	0.035	0.002	0.043	0.001	0.024	0.035
0.9	0.027	0.001	0.022	0	0.031	...	...	...
0.95	...	...	0.013	0.001	...	...	...	...
1.00	0.005	0	0.008	0.007	0.003	0.003	...	...



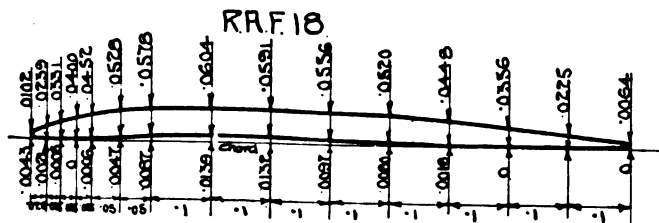
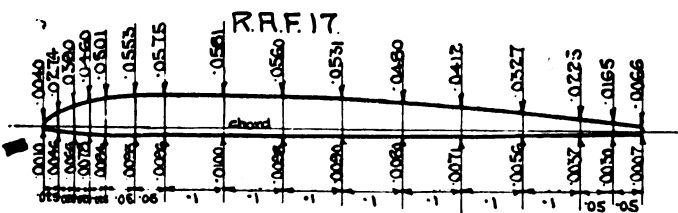
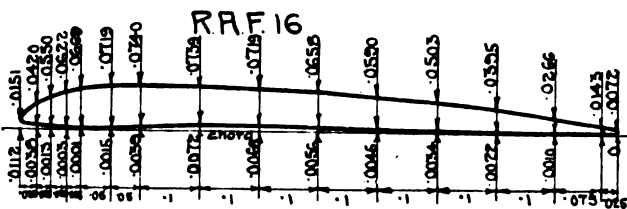
533.65.013

Note.—The dimensions are in terms of the chord.





DE-DA (Detachable Data) System.
 R. Birlase Matthews' Patents (provisionally protected). U.S. Patents applied for.



533.65.05

74

U.S. Pat. 4,146,441 (Detachable Data) System
& 4,146,442 (In Place Alphanumeric Patents) operationally protected. U.S. Patents applied for.

to abscissæ of speeds in miles per hour. The various points where the curves intersect indicate the top speeds; and the maximum ordinate between the curves gives the horse-power available for climbing.

It is often assumed that the available airscrew horse-power at the speed of maximum efficiency of the airscrew equals 75 per cent. of B.H.P. of engine, and falls off from that value according to a parabolic law to zero at zero. However, it is more accurate to employ the curve of airscrew efficiency at varying speeds obtained from the airscrew calculations.

Unfortunately for those who are interested in the quantity production of aeroplanes, the service life of the machines is only too brief, as a rule barely six months. The reason for this being that, after a period of six months, other nations will have been able to incorporate all the best points of the aeroplane, thus rendering it out of date. An aeroplane can only be said to be of real value when it has either a better performance, or makes a superior fighter. Performance may best be described under the heads of improved speed, better climbing, greater endurance, or a combination of these qualities. From a consideration of fighting requirements, manoeuvrability, unimpeded view, and improved gun positions are of all importance.

To achieve these features, a designer attempts first to increase the horse-power-weight ratio. This may be accomplished by the installation of engines of greater horse-power, or of lighter weight per horse-power, accompanied by close and accurate design, with elimination of all redundant weight. Secondly, he would endeavour to decrease wing or structure resistance. Wind tunnel experiments afford much useful information in this direction. Thirdly, the possibility of evolving a new arrangement of the supporting planes would be taken into consideration.

In the light of present knowledge, the most efficient aeronautical arrangement for an aeroplane is the unstaggered, equal planed biplane, with the gap equal to the chord. The aspect ratio, in accordance with the gross weight, should vary from 5 in small machines to 10 in large ones. Low resistance aerofoils are essential, and the wing tips must be properly shaped.

At 45 m.p.h., at the maximum lift angle:—

Low resistance aerofoil	-	-	-	5 lbs. per square foot.
Medium "	"	-	-	6 lbs. " "
High "	"	-	-	7½ lbs. " "

High lift aerofoils economise weight and consequently area. As this results in reduced stresses, weight is again cut down. Further, this weight reduction means a smaller tail area or length of body.

A reduction in weight and area means an improved view and easier handling—except in dives.

An increase beyond 17 lbs. per horse-power means that the speed range for the low resistance type exceeds that of the high lift type.

Speed range, 50-150 m.p.h. low resistance.

" " 50-125 " medium lift.

" " 50-100 " high lift.

The R.A.F. 6 section is an example of a medium lift.

Excess horse-power is of value in a low resistance aerofoil, but it becomes wasteful as the lift is increased. Practically there is very little difference in the climbing rates of any aerofoil, despite the weight handicap of the low lift type.

As an example of the required performance of a modern aeroplane, it is interesting to note that German specifications call for a single-seater fighter that will climb to 10,000 ft. in ten minutes or less, and travel at 130 m.p.h. at 12,000 ft., with a ceiling of 25,000 ft. The requirements for a two-seater reconnaissance machine are: climb to 10,000 ft. in fifteen minutes; speed at that height, 100 m.p.h., with three hours' fuel; and ceiling of 15,000 ft.

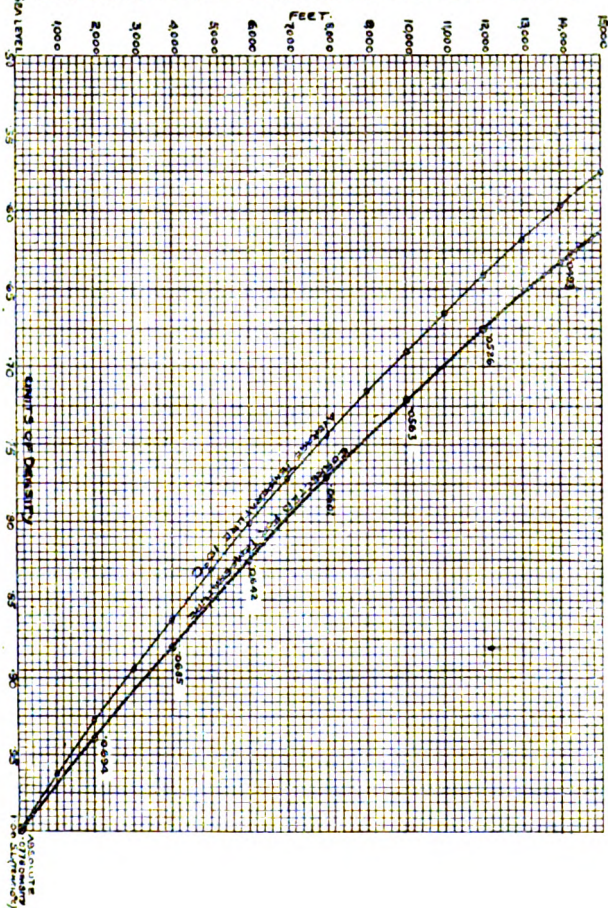
Angle of Climb.—This averages from 1:8 to 1:10. A very good instance would be 1:5; however, it may be as low as 1:16.

ABSOLUTE CEILING OF AN AEROPLANE

(Approximation)

Weight. Lbs. per H.P.	Lead in Lbs. per Square Foot of Supporting Surface.					
	5	6	7	8	9	10
	Fect.	Fect.	Fect.	Fect.	Fect.	Fect.
5	...	30,000	29,600	29,200	28,800	28,400
6	29,300	28,700	28,250	27,700	27,400	27,000
7	28,200	27,400	26,800	26,200	25,800	25,500
8	27,000	26,000	25,500	24,800	24,300	23,800
9	25,700	25,000	24,200	23,500	22,800	22,300
10	24,600	23,700	23,000	22,200	21,500	20,800
11	23,500	22,600	21,700	20,900	20,100	19,400
12	22,500	21,500	20,600	19,700	18,900	18,200
13	21,500	20,500	19,500	18,500	17,700	16,800
14	20,500	19,400	18,400	17,400	16,500	15,600
15	19,500	18,400	17,400	16,300	15,300	14,500
16	18,700	17,400	16,300	15,200	14,300	13,500
17	17,800	16,500	15,400	14,200	13,300	12,500
18	17,100	15,700	14,500	13,500	12,000	11,600
19	16,500	15,000	13,800	12,700	11,700	10,900
20	16,000	14,400	13,200	12,000	11,000	10,400

DENSITY OF AIR AT VARIOUS HEIGHTS (TEMP 10°C at SEAL BAR HT. 29.92, WHEN ALLOWANCE HAS BEEN MADE GRADE OF TEMPERATURE OF 15°C FOR EVERY 1000 FT. OF ALTITUDE; THE LIGHT CURVE SHOWS VARIATION OF DENSITY WITH ALTITUDE ASSUMING A CONSTANT MEAN AIR TEMPERATURE OF 10°C.



The Maximum Size of an Aeroplane

In accordance with the laws of similitude of geometrically similar structures, aeroplanes have already reached their limit in size and carrying capacity, owing to the fact that the weights increase as the cubes of the similar dimensions, while the areas of the supporting surfaces only increase as the square. Hence the ratio of weight to area continuously increases as the linear dimensions. If, however, a large aeroplane is so designed as **not** to be a geometrical copy of a small one, there seems to be no practical reason why there should be any limit within reason to their size. The requirements that are necessary for the design of specially large aeroplanes are as follows :—

(a) That with an increase in the overall dimensions, the weight must not increase faster than as the square of such dimensions.

(b) The larger elements of the construction must be designed in such a manner as to secure for a given wing area the minimum weight of secondary structure.

(c) The combination of multiple wing elements in such a way as to reduce to a minimum the interference of one with another.

(d) The incorporation of variable wing area or variable wing camber.

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METHOD OF ESTIMATING THE STRESSES IN PLANES

1. Assumptions and Data.—A definite example may be taken for the purpose of illustration, as shown in plan and section respectively, in the diagrams which follow on the next page.

It should be noted that the dimensions and weights selected are merely given for the purpose of illustrating the application of the method of calculation.

(All calculations in this example have been done on a slide rule, and are only, therefore, correct to the nearest figure.)

Total weight of aeroplane	1,400 lbs.
Total weight of main plane	200 „

2. Distribution of the Load between the Planes.—The biplane effect is such, that the load per square foot is greater on the top than the bottom plane.

The relative loading is in the proportion of 100 to 80, and has been determined from experiments in pressure distribution.

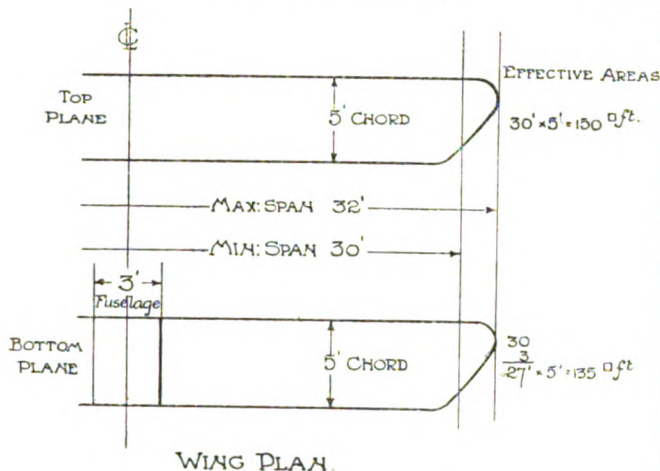
The total equivalent surface area with lift per square foot equal to the lift per square foot of the bottom plane

$$= 135 + \frac{150}{8} = 135 + 18.75 = 153.75 \text{ sq. ft.,}$$

i.e., the 150 sq. ft. effective area of top plane = 187.5 sq. ft., if the load per square foot is the same as on the bottom plane.

LOAD DISTRIBUTION

533.65



WING PLAN.

Load Distribution

The total weight of the aeroplane is divided between the top and bottom plane as follows:—

$$\text{Supported by top plane, } \frac{1400 \times 187.5}{322.5} = 820 \text{ lbs.}$$

$$\text{Supported by bottom plane, } \frac{1400 \times 135}{322.5} = 580 \text{ lbs.}$$

The weight of the planes is supported directly by the aerodynamic lift under the planes.

The load on the planes is external, and to determine same, the weight of the planes themselves must be deducted from the lift of the planes.

Further, the weight of the planes is assumed to be proportional to the area.

$$\text{Weight of Top Plane} \quad - \quad - \quad - \quad \frac{200 \times 150}{285} = 112 \text{ lbs.}$$

$$\text{Weight of bottom plane} \quad - \quad - \quad - \quad \frac{200 \times 122}{285} = 96 \text{ lbs.}$$

$$\text{Net load on top plane} \quad - \quad - \quad - \quad 820 - 112 = 708 \text{ lbs.}$$

$$\text{Load per square foot} \quad - \quad - \quad - \quad \frac{708}{150} = 4.7 \text{ lbs. sq. ft.}$$

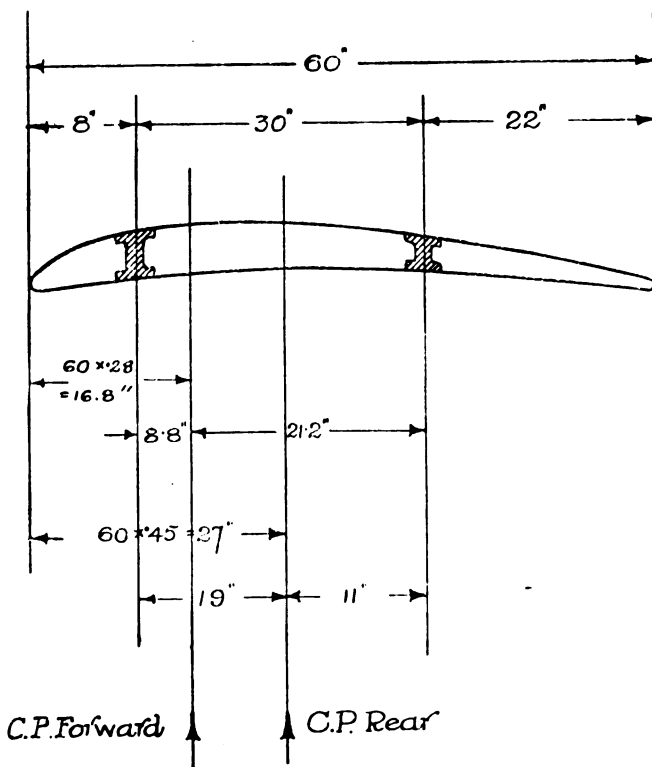
$$\text{Net load of bottom plane} \quad - \quad - \quad - \quad 580 - 96 = 484 \text{ lbs.}$$

$$\text{Load per square foot} \quad - \quad - \quad - \quad \frac{484}{135} = 3.6 \text{ lbs sq. ft.}$$

Distribution of Load on Spars

The centre of pressure (C.P.) varies with different angles of incidence.

Assume that for this example the variation is between 1° to 15° , and that the diagram herewith represents the aerofoil.



The dimensions above the figure are assumed.
The dimensions below the figure are calculated.

The movement of C.P. is from 0.28 to 0.45 of the chord, and measured from the leading edge.

Load per foot run.—

On top plane $4.7 \times 5 = 23.5$ lbs.

On bottom plane $3.6 \times 5 = 18$ lbs.

When the C.P. is forward, the front spar is obviously loaded to a greater extent than the rear spar.

When the C.P. is towards the rear, the rear spar carries the heavier load.

Max. Load per foot.—

On front top spar $= 23.5 \times 21.2 \div 30 = 16.6$ lbs.

On front bottom „ $= 18 \times 21.2 \div 30 = 12.7$ „

On rear top „ $= 23 \times 19 \div 30 = 16.6$ „

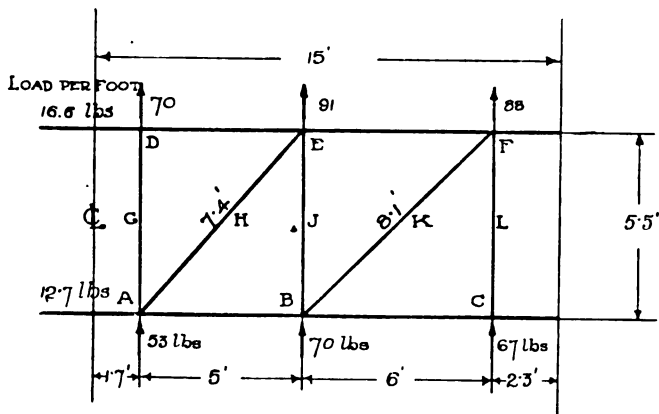
On rear bottom „ $= 18 \times 19 \div 30 = 11.8$ „

Bending Moment on Spars.—Determine the B.M., treating the spars as continuous beams.

Points of Support

Bottom Plane Spars.—Strut hinges. Pin front.

Top Plane Spars.—Strut hinges, see figure for alternative case if lift wires are offset.



FRONT SPARS, WIRES & STRUTS.

Resultant Loads at—

$$A = 12.7 \left(1.7 + \frac{5}{2} \right) = 53 \text{ lbs.}$$

$$B = 12.7 \left(\frac{5}{2} + \frac{6}{2} \right) = 70 \text{ ,,}$$

$$C = 12.7 \left(\frac{6}{2} + 2.3 \right) = 67 \text{ ,,}$$

$$D = 16.6 \left(1.7 + \frac{5}{2} \right) = 70 \text{ ,,}$$

$$E = 16.6 \left(\frac{5}{2} + \frac{6}{2} \right) = 91 \text{ ,,}$$

$$F = 16.6 \left(\frac{6}{2} + 2.3 \right) = 88 \text{ ,,}$$

$$\text{Load in wire} = (88 + 67) \times \frac{8.1}{5.5} = 228 \text{ ,,}$$

$$H \quad 91 + 70 \times \frac{7.4}{5.5} = 216 \text{ ,,}$$

The B.M. diagrams for each portion of the spar are taken as separate.

The upper portion of the following diagram shows the loads, etc., and refer to front, top and bottom spars.

Front Top Spar.—Load, 16.6 lbs. per ft.

Front Bottom Spar.—12.7 lbs. per ft. run.

To draw B.M.—Take one bay at a time.

w = load lbs. per foot run.

l = span of bay under consideration.

$$\frac{w \times l^2}{8} \text{ gives B.M.}$$

Draw parabola.

Work every case out.

Taking end as common cantilever.

$$w \times l^2 = \text{B.M.}$$

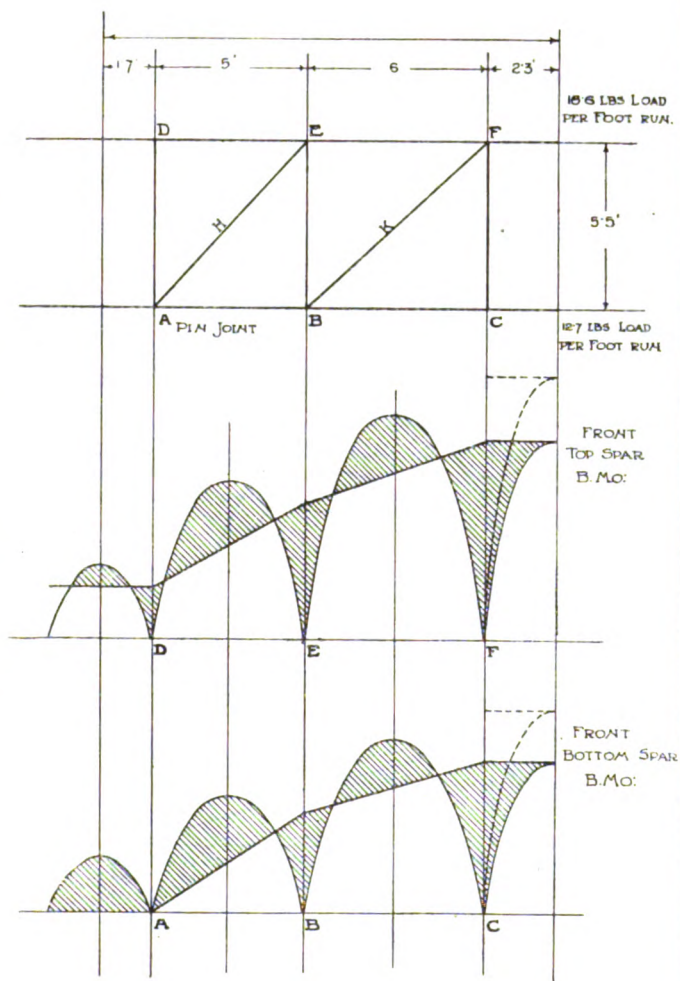
Draw $\frac{1}{2}$ parabola.

It is usual to make allowance for wash out. An approximation is to take 75 per cent. of the B.M. calculated. Some designers prefer to take the maximum load without any allowance. This is a point to be settled by the designer. After drawing the parabolic curves, the "Theorem of three moments" should be applied to determine the reactions, which are then set down, thus giving the complete figures.

The above method is sketched out on the assumption that the

POINTS OF SUPPORT

533-65

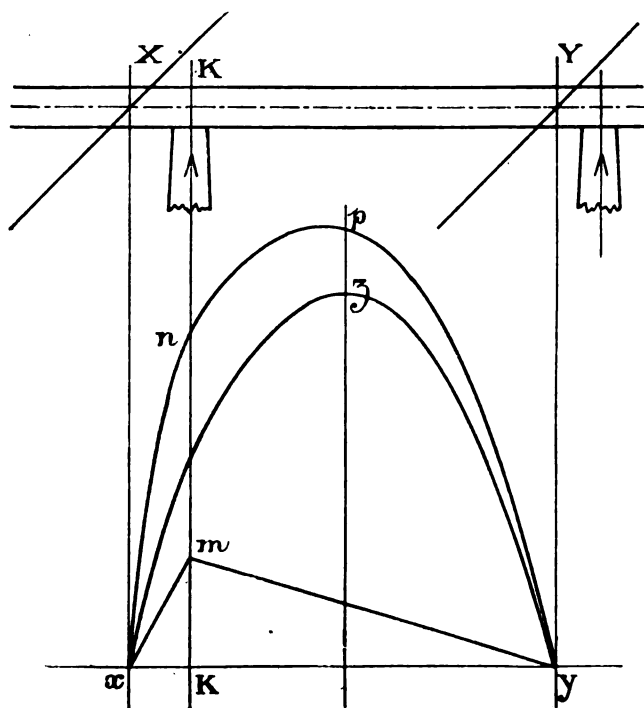


centre lines of the wires and the struts intersect at neutral axis of the spar.

Where there is offset, corrections are made as follows :—

B.M. is taken as the bay length between the intersection of the lift-wires and the neutral axis of the spar.

The thrust due to the strut produces B.M., which is to be added to the B.M. on the bay produced by the spar loading.



xzy = B.M. DUE TO DIST. LOAD.

xmy = " " " THRUST OF STRUT K.

$xnpy$ = TOTAL B.M.

The B.M. resulting from the thrust P of the strut is:—

$$\frac{P \times l_1 \times l_2}{l}$$

The theorem of three moments should be carefully studied, see notes a little further on. (539.3.)

Stresses Due to Drift

The maximum load on the plane due to the drift may be taken as a uniformly distributed horizontal load of $\frac{1}{2}$ the lift, and equally divided between the spars.

Allowance must be made for internal drift wires.

From the total B.M. determined the spar section is derived.

Other important factors that have to be taken into consideration are:—

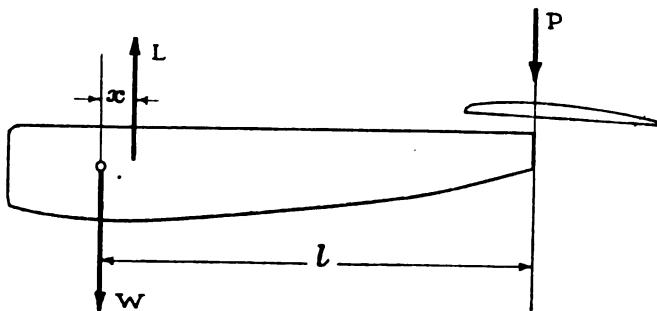
The space available, the material, and the factor of safety allowed.

The rear top and bottom spars should be treated in the same manner.

Strength of Fuselage

When an aeroplane is flying level, all the forces acting on it are in balance.

Forces are shown on the sketch herewith:—



W = Weight of machine acting through C.G.

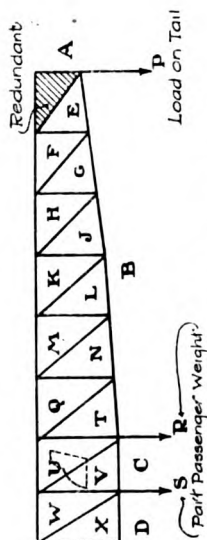
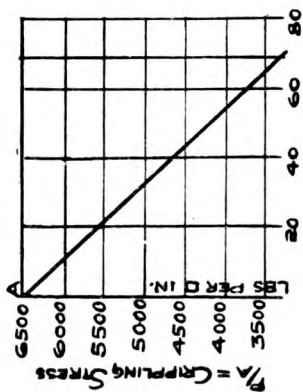
L = Lift upon main plane.

P = Load on tail.

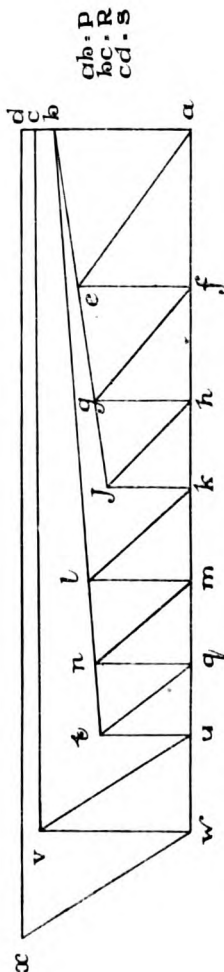
Load required to balance

$$= P = \frac{Wx}{l - x}$$

$$L = WP.$$



FUSELAGE LINEAR SCALE DIAGRAM.



FORCE DIAGRAM.

*De-D.A. (Detachable Data) System
R. Borlase Matthews' Patents (provisionally protected). U.S. Patents applied for.*

If **L** is forward of **W** the direction of **P** is upward.

The usual procedure is to set down to scale the frame drawing of the fuselage, and to then determine the stress in the members by graphics or Ritter's method of moments.

The rudder and the fin impose loads operating in a lateral direction. These are dependent upon the area of the rudder and the fin, and are maximum when the rudder is swung round to its maximum inclination.

From the speed of the aeroplane the air pressure and the area of the surface, an approximation may be made of the force operating at the tail and acting in a horizontal direction.

The resulting stress on the fuselage frame may be worked out in a similar manner to the tail load, and the total stress in the various members can then be added to the stress in the same members as the tail load diagram.

Duplicated Bracing Wires.—These wires are usually of such strength that when one is broken the aeroplane structure will still have a load factor of 6. The term "load factor" must not be confused with "factor of safety," for it expresses the number of times the maximum loads occurring in flight, can exceed the loads occurring in normal horizontal flight before the aeroplane will suffer permanent damage, the latter occurring at stresses beyond the elastic limit.

In the design of joints, provision should be made for withstanding elastic limit loads as follows:—

(a) One wire broken and the other taking loads corresponding to a load factor of 6.

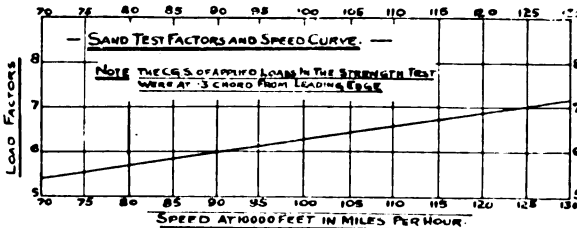
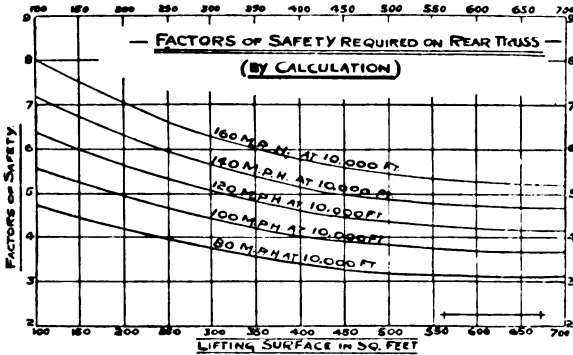
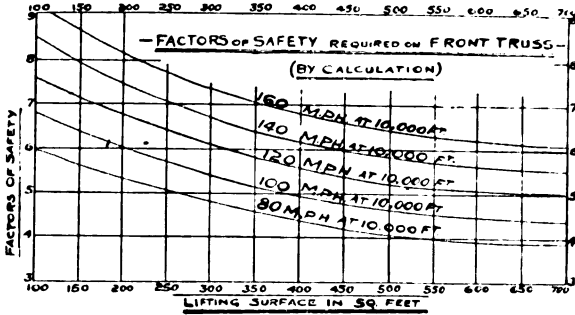
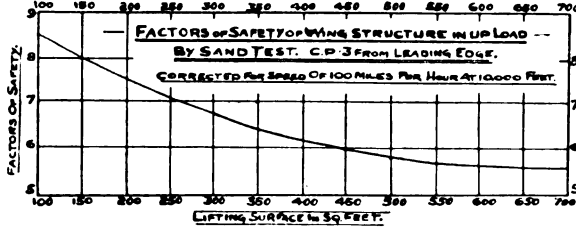
(b) Both wires taking exceptional load, one of them having a load equal to its failing load, and the other carrying the remainder of the total load.

The total load in this instance should correspond with the given load factor, e.g., if the duplicated wire be specified as $2 \times 5,400$, and the load factor be 9, then the total load on the joint will be $2 \times 5,400 = 8,100$. The joints should be able to withstand this load when one wire is under a strain of 5,400 lbs., and the other wire has a load of $8,100 - 5,400 = 2,700$ lbs.

It should be noted that the rated loads in wires do not make any allowance for the splicing of cables or the bending of wires.

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AIRSCREWS

Tractors and Propellers—Airscrew Classification—Notation—Principles of Design—Graphical Method—Blade Shape Factors—Interference—Efficiency at Various Speeds—Required Strength—R.P.M.—Weights—Experimental—Testing—Airscrew Finishing—American Standard Shaft.

An airscrew is described as a tractor when placed in front of the main planes, and as a propeller when fitted behind. It is a device for converting engine torque into thrust by throwing back a column of air. It is virtually a rotating plane, and so its design may be based upon a knowledge of the data associated with that of moving planes in the air. An airscrew blade, similar to the wing of an aeroplane, should have a large aspect ratio (usually about 6).

Tractor screws differ slightly in design from propellers or pusher screws. The reason for this is that, given the same velocities of the aeroplane, the tractor has a greater velocity of entry into the air than is the case with the propeller, for the planes exert a certain amount of viscous drag upon the air; in other words, a tractor screw used as a propeller would have a greater slip and consequently lower efficiency.

The pitch of an airscrew is the distance that would be travelled by a screw in one revolution if there was no slip, i.e., $\frac{V}{n}$.

Slip is necessary to produce thrust, just as the angle of incidence is essential for the lift of an aeroplane. It must be borne in mind that the angle of incidence of an element of an airscrew blade is less than it appears to be, as the airscrew advances when revolving, and lessens further as the translational velocity increases.

Wide airscrew blades are impracticable, for if the width is too great, the lift of the following blade is affected by the wash of the leading blade, as is found to be the case with a biplane if the gap-chord ratio is insufficient (it should be between 0.8 and 1.2). Hence a form of Archimedean screw, as proposed by several inventors, cannot be entertained.

In the case of the design of present-day airscrews, the most generally employed basis is that known as the "blade element" or "aerofoil analogy," due to Drzewiecki. A brief outline of the general principles on which it is based, and an indication of the methods followed in design, are given herewith. These are based on "Notes

on Propeller Design," by North and Riach, in *Aeronautics*, 1914-1915; and the book on "Airscrews," by Riach (refer to the Bibliographical section of this "Aviation Pocket-Book" for particulars of airscrew literature).

NOTATION

The following characters are utilised on the succeeding pages:—

n = Speed of revolution per second.

V = The horizontal or translational velocity of the aircraft in feet per second.

P = The effective pitch = $\frac{V}{n}$.

A = The angle of the effective helix.

x = The radius under consideration.

α = The angle of attack.

L = Lift.

D = Drift.

K = A constant (depending upon the units used in the measurements of the quantities V and S).

K_y or $\phi(x)$ = The vertical component.

K_x = The horizontal component.

γ = The gliding angle of the aerofoil section under consideration, at a given angle of incidence.

T = Thrust in a direction parallel to the line of advance.

S = The area of the aerofoil surface.

b or $f(x)$ = The blade width.

N = Number of blades.

η = Efficiency.

M = Torque.

r_1 = Length of blade from the axle centre.

r_2 = Length from centre to the extreme portion of the blade where stream lining stops,
i.e., $r_1 - r_2$ = Effective blade.

H = Horse-power.

D = Permissible diameter of airscrew.

$\phi(x) = \frac{K_y}{K_x} = \tan \gamma$.

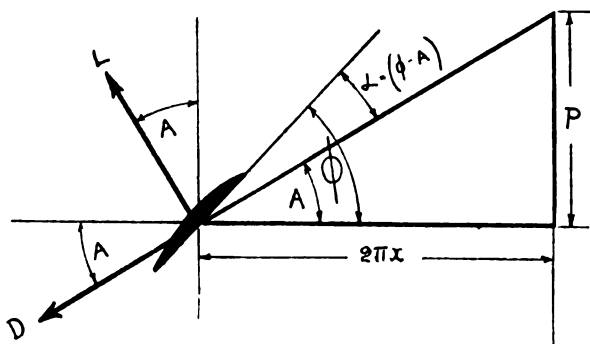
For the purpose of these notes all units will be taken as pound, foot, second.

PRINCIPLES OF DESIGN

Each element of the blade is considered to be an aerofoil moving along a helicoidal path, with a definite angle of attack. The effective pitch P (i.e., the pitch which would cause the aircraft to advance at its velocity V , if there were no slip) is $\frac{V}{n}$. The angle of the effective

helix A, at any radius from the boss centre, is $\tan^{-1} \frac{P}{2\pi x}$, where x is the radius considered.

The illustration herewith shows an elementary blade section moving up a helicoidal or inclined path. The vertical ordinate denotes $P = \frac{V}{n}$. A is the angle of the effective helix, and α the "angle of attack" of the element. The reaction on the element may be resolved along and normal to the helicoidal path. The



resultants are indicated on the figure by L and D , representing the lift and drift of the element. These may be expressed as $L = K_y SV^2$, and $D = K_x SV^2$.

From this—
$$\frac{L}{D} = \frac{K_y}{K_x} = \cot \gamma, \quad \text{or,} \quad \frac{K_x}{K_y} = \tan \gamma.$$

The thrust of the element, normal to the disc of revolution (i.e., in a direction parallel to the line of advance of the whole airscrew), is given by:—

$$T = L \cos A - D \sin A.$$

The drift parallel to the disc of revolution

$$= L \sin A + D \cos A.$$

The values of L and D depend on the blade width, the shape of the section, and the value of α , at the particular radius under consideration. That is to say, K_y , $\frac{K_x}{K_y}$, and S may all be expressed as functions of the radius (x). (For an elementary section, s = the blade width b at radius x .)

For each revolution of the airscrew the work done is the product of the total thrust, the distance through which it is exerted and the number of blades, or:—

$$\text{Work done by airscrew per revolution} = T \times \frac{V \times N}{n} = T \times P \times N; \text{ and}$$

Work done by engine per revolution at n revs. per sec. = $M \times N \times 2\pi$

(where M is the torque), whence the efficiency, $\eta = \frac{T \times P \times N}{M \times N \times 2\pi}$.

The drift of the element may be conveniently expressed as :—

$$f(x) \cdot \psi(x) \cdot n^2 \sqrt{P^2 + 4\pi^2 x^2} (P + 2\pi x \cdot \psi x),$$

V being expressed as $n \sqrt{P^2 + 4\pi^2 x^2}$, for $\sqrt{P^2 + 4\pi^2 x^2}$ is the length of the helix traversed by the element of blade per revolution. [The hypotenuse of a right-angled triangle, with a base of $2\pi x$ —half the diameter of the airscrew—and perpendicular equal to the pitch.]

The work done per second by the engine in turning the airscrew is

$$2\pi n^3 N \int_{r_2}^{r_1} x \cdot f(x) \cdot \psi(x) \cdot [P + 2\pi x \cdot \psi(x)] \sqrt{1^2 + 4\pi^2 x^2} \cdot dx,$$

consequently the horse-power is equal to the above expression divided by 550.

The evaluation of the definite integral,

$$\int_{r_2}^{r_1} x f(x) \cdot \psi(x) (P + 2\pi x \cdot \psi(x) \sqrt{P^2 + 4\pi^2 x^2}) dx,$$

would be very laborious, and would involve the determination of approximate equations for $f(x)$, $\phi(x)$, and $\psi(x)$.

A graphical method may therefore be utilised with advantage.

1. Draw to any convenient scale a curve of blade shape [$f(x)$], the ordinates representing *proportional* widths. In drawing this curve account must be taken of the three considerations of blade shape explained later on, under "blade shape factors."

2. Plot the curve of the function—

$$x, f(x), \psi(x), (P + 2\pi x \psi x) \sqrt{P^2 + 4\pi^2 x^2},$$

the values of $f(x)$ being obtained for the curve already drawn; while the values of $\phi(x)$ and $\psi(x)$ are taken from a curve of coefficients of suitable sections.

3. The area enclosed by the curve drawn in (2) and the vertical ordinates at r_1 and r_2 has the approximate area of the definite integral that is required. The ratio of the scale chosen for the

vertical ordinates of the curve $f(x)$ to the time ordinates is given by

$$2\pi n^2 N \text{ (area of figure)'}^2$$

From this the blade width at any point may be at once obtained.

Owing to the inflow of air in front of the blade the value of the coefficients $\phi(x)$ are decreased, and a correction is necessary to allow for this. The correction factor ascertained by experiment is about $\left(\frac{100}{75}\right)$, and the blade widths found should be multiplied by this factor.

The total efficiency of the propeller is given by the expression

$$\eta = \text{Efficiency} = \frac{P \int_{r_2}^{r_1} f(x) \phi(x) \cdot (2\pi x - P\psi(x)) \sqrt{P^2 + 4\pi^2 x^2} \cdot dx}{2 \cdot \pi \int_{r_2}^{r_1} x \cdot f(x) \cdot \phi(x) \cdot (P + 2\pi x \cdot \psi(x)) \sqrt{P^2 + 4\pi^2 x^2} \cdot dx}$$

The values of the definite integrals may be obtained by a similar method and the efficiencies determined. The efficiency is approximately proportional to the pitch diameter ratio.

For purposes of approximate calculations, when the propeller efficiency is not definitely known, it is usual to assume an efficiency of 70 to 75 per cent., though in practice the efficiency may be as low as 50, or as high as 80 per cent.

BLADE SHAPE FACTORS

In designing an airscrew for a particular aeroplane, the following data are normally available—(a) horizontal velocity, (b) rotational velocity of engine, (c) horse-power of engine, and (d) the permissible diameter.

The blade shape is influenced by three considerations:—

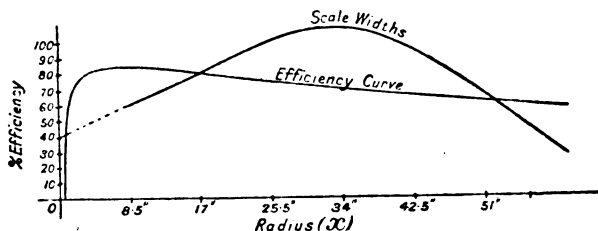
1. The limits of structural convenience.
2. The interfering or disturbing action which one blade exerts upon the air dealt with by another.
3. The relative efficiencies of the various parts of the blade as determined by their position.

The general form of the efficiency expression is—

$$\frac{\tan A [1 - \tan A \psi(x)]}{\tan A + \psi(x)}$$

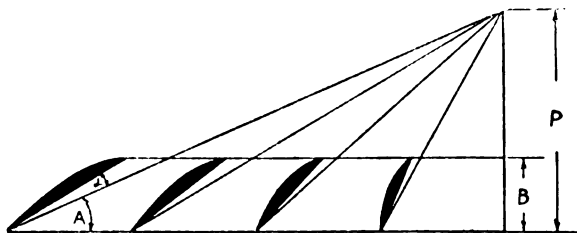
For a propeller having average blade sections this reaches a maximum when A is in the neighbourhood of 42° . An examination

of characteristic curves of the efficiencies of elements plotted against radii indicates that the most efficient portion of an airscrew blade



A Characteristic Efficiency Curve.

is towards the centre of the propeller boss. Constructional reasons, however, seldom allow the blade to be widest at this point.



The above figure shows the limitation that construction places upon blade widths at varying radii. B is the greatest permissible depth of boss, then the width of the blade $b = B (\cos A + a)$.

In considering **interference**, the blades of the airscrew may be considered as similar to the planes of a multiplane, the gap of which is equal to the vertical distance between their two helicoidal paths.

This distance is $\frac{P \cos A}{N}$, and it should be between three and four times the blade width.

The choice of blade sections at various radii is largely governed by considerations of strength.

EFFICIENCY AT VARIOUS SPEEDS

It is necessary to be able to determine approximately the efficiency of an airscrew at different speeds of translation from that for which it was designed. The result of a variation of the velocity

V will be a new value for $\frac{V}{n}$, and a variation in the curves $\phi(x)$ and $\psi(x)$, since the helix angles being different, the angle of attack will not be the same. New curves for $\phi(x)$ and $\psi(x)$ can readily be plotted for the new angles of attack. Wind channel tests on suitable sections are given on page 89 of the "Technical Report of the Advisory Committee for Aeronautics, 1911-1912," and the necessary data for plotting the revised curves $\phi(x)$ and $\psi(x)$ may be obtained from them.

To determine the efficiency at any particular speed, the procedure indicated in (4) should be followed, making the necessary changes in P, $\phi(x)$, and $\psi(x)$.

STRENGTH OF BLADES

It will be necessary to verify the suitability of the chosen section from the point of view of strength. It is important that the blade should not have a tendency to "whip."

The blade is subjected to two loads: (1) centrifugal and (2) bending. An approximation of the intensity of stress due to these can readily be obtained by the usual method of ordinary engineering practice. The stress due to bending may perhaps most easily be determined by integrating graphically the load grading curve and obtaining the S.F. and B.M. diagrams. The blade of an airscrew is of course a cantilever subjected to irregularly distributed load. The loading is usually assumed uniplanar. It is not usually necessary to consider torsional stresses on the blade, as these are suppressed as much as possible in laying out the propeller.

Experience has shown that American walnut is the most suitable wood for airscrew work; failing this, mahogany (Honduras) may be used. It appears to be generally agreed that a safe working stress for both these materials is in the neighbourhood of 2,000 lbs. per square inch. (For further particulars of woods, refer to Division 674 of this "Aviation Pocket-Book.")

In the event of the stress calculation showing that the strength of the chosen sections is inadequate, the blade may be strengthened by slightly cambering the under surface of the section. It does not appear that this has any appreciable effect on the aerodynamic properties of the section.

GENERAL NOTES

As an indication of the possible directions in which enhanced efficiency may be anticipated, Mr M. A. S. Riach sums up the situation as follows:—

- (1.) High aspect ratio (multiple blades).
- (2.) Higher lift-drag value sections.
- (3.) Correct (V/nd) values for maximum efficiency.

(4.) Wide blades only employed in conjunction with the correct chord angles.

(5.) Correction of the allowance for the amount of end tip loss.

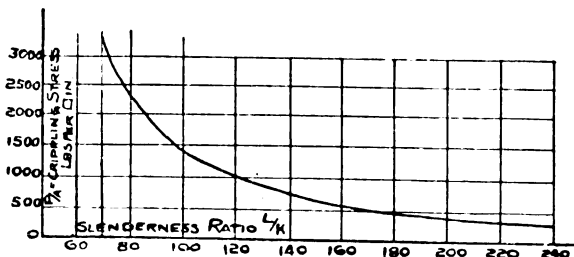
(6.) Greater thrust at the same forward and rotational speed, and higher efficiency, though more driving power required, as compared with two-bladed screws.

(7.) Slight forward rake, to convert stresses into tensions, and so permit of heavier sections.

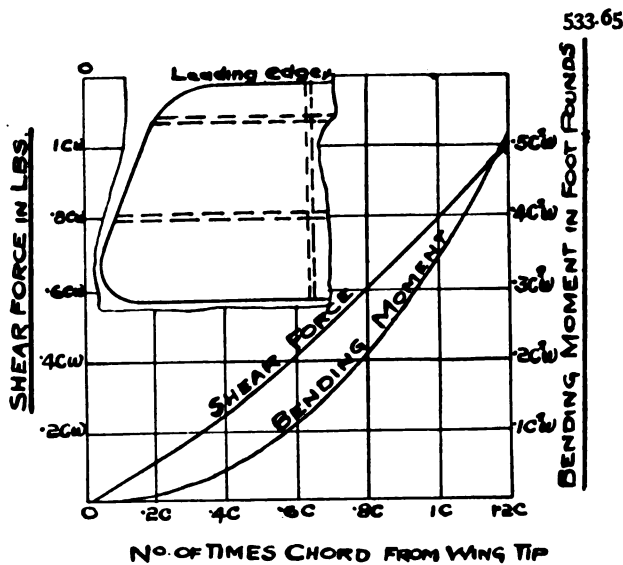
Airscrew Slip Stream.—The slip stream from an airscrew flows backwards and downwards, and is rotating. In a great many designs of aeroplanes the fin and the rudder are situated above the centre line of the slip stream, which latter, therefore, meets them on one side only. The effect of this is to tend to turn the aeroplane to one side continuously, *e.g.*, if the airscrew revolves clockwise, when viewed from the pilot's seat, the aeroplane will tend to turn to the left—to overcome this, the rudder must be held in the opposite direction. It will be appreciated that as a result of the airscrew slip stream, that when the engine is opened out the aeroplane will tend to (a) put its nose up, and (b) to swing round one way. On closing down the engine the reverse effect takes place, for the aeroplane will put its nose down, and the tendency to swing round one way will be reduced.

Airscrew Torque.—When the engine is running there is a tendency for the aeroplane to turn over in a direction opposite to that of the revolution of the airscrew. This effect is, however, very slight, and can be practically eliminated either by (a) increasing the angle of incidence on one side of the main planes, and decreasing it on the other (in practical parlance this is known as rigging for "wash in" and "wash out" respectively), or alternatively (b) by providing more droop on the ailerons on one side and less on the other.

533-65



Refer to pp. 78-85



ANIMAL FLIGHT

533-68

CONSIDERABLE attention was given by the earlier designers of flying machines to the flight of insects and birds, but so far not much information has been gleaned that can be adapted for man's assistance in the construction of aeroplanes or airships. At the same time careful study of animal flight can teach much about the air and its vagaries, which might otherwise be very difficult to discover. This is instanced particularly in observations deduced from the soaring of big birds.

There are four forms of bird and insect flight—(a) soaring, (b) gliding, (c) flapping, and (d) leaping. Professor J. E. Marey's photographic analysis of flight has shown it to be of a most complex character, for though the wings reciprocate and act somewhat like a single-bladed airscrew, at the dead centre they reverse their pitch along the terminal position. The wings are moved diagonally forward on the down stroke, and backward on the up stroke. Further, the axis of the body oscillates with each stroke. Hence it would seem highly impracticable to devise a suitable mechanism that would exactly copy the flight of a bird. Wing propulsion probably possesses no advantage on the score of efficiency over a well-designed airscrew, and certainly the latter has the mechanical advantage.

Dr Magnan has made a practical application of his studies of animal flight in the evolution of empirical formulæ therefrom for the design of monoplanes :—

If :—

P = total weight of machine (including load in grammes).

S = area in square centimetres.

l = length in centimetres.

$l = \sqrt[3]{P}$, and $S = \sqrt[3]{P^2}$.

Then :—	Example. P = 512 kg.
$\frac{\text{area of wings}}{\sqrt[3]{P^2}} = 23.2$	14.85 sq. m.
$\frac{\text{weight of wings}}{P} = 197$	100.86 kg.
$\frac{\text{span of wings}}{\sqrt[3]{P}} = 13.3$	10.64 m.
$\frac{\text{chord of wings}}{\sqrt[3]{P}} = 2.36$	1.89 m.
$\frac{\text{length of body}}{\sqrt[3]{P}} = 5.9$	4.72 m.
$\frac{\text{length of tail}}{\sqrt[3]{P}} = 2.6$	2.08 m.

The Ponnier racing monoplane designs were based upon the above formulæ.

The principal data connected with bird and insect flight that are of special interest to the art of aviation, are given in the following tables :—

WING SURFACE IN INSECTS AND BIRDS (De Lucy)

<i>Insects.</i>		<i>Birds.</i>	
Name.	Square Feet of Wing Surface for each Lb. of Weight.	Name.	Square Feet of Wing Surface for each Lb. of Weight.
Gnat	48.77	Swallow . . .	4.87
Ladybird . . .	22.06	Sparrow . . .	2.72
Dragon-fly . .	21.6	Turtle dove . .	2.13
Bee	5.22	Pigeon	1.27
Bluebottle-fly .	5.6	Stork	0.97
Cockchafer . .	5.16	Vulture	0.82
Stag beetle (female)	4.65	Crane	0.41

ANIMAL FLIGHT

533.68

SPAN AND LOADING OF SOARING BIRDS (Dr Hankin)

Name.	Span in Feet.	Loading in Lbs. per Sq. Ft.
Cheel or pariah kite - - - - -	4	0.55
Scavenger or white vulture - - - - -	5	0.87
Common vulture or white-backed vulture - - - - -	7	1.13
Black vulture - - - - -	6.5	1.23
Adjutant (stork species) - - - - -	9	1.54

MILES PER HOUR

(Floring)

Carrier pigeon, good weather - - - - -	26 m.p.h.
" " moderate weather - - - - -	20 "
" " bad weather (Hildebrandt) - - - - -	15 "
" " good weather - - - - -	39.6 "
Swallow " - - - - -	74.4 "

The last two tests were made by trained birds over distances of 145 and 93 miles respectively.

FLIGHT OF INSECTS AND BIRDS (Marey)

Name.	Beats of Wing per Second.	Hundredths of a Second for Each.
<i>Insects.</i>		
Common fly - - - - -	330	.31
Drone - - - - -	240	4.2
Bee - - - - -	190	5.3
Wasp - - - - -	110	9.1
Moth - - - - -	72	1.4
Dragon-fly - - - - -	28	3.6
Butterfly - - - - -	9	11.1
<i>Birds.</i>		
Sparrow - - - - -	13	7.7
Wild duck - - - - -	9	11.1
Pigeon - - - - -	8	12.5
Screech owl - - - - -	5	20.0
Buzzard - - - - -	3	33.3

WING SURFACE OF SOARING BIRDS ("Flight")

Bird.	Weight.		Surface.	Span.	Sq. Ft. of Wing Surface.
	Lbs.	Oz.	Sq. Ft.	Ft.	Per Lb.
Golden eagle - -	7	0	6	8	0.86
Egyptian vulture - -	4	0	4	4½	1.0
Sea eagle - -	7	0	6	8	0.86
Common kite - -	1	8	3	4½	1.7
Osprey - -	3	0	3	4½	1.0
Heron - -	3	8	3½	4½	0.95
Goshawk - -	0	10	1	2½	1.6
Sparrow-hawk - -	0	6	0¾	1½	2
Stork - -	5	0	4	6½	1.3
Average - -	...		...	...	1 to 2

A number of naturalists and others have very carefully studied bird and insect flight, and those who are more interested in the details should refer to the writings of J. E. Marey, de Lucy, Parseval, Hildebrandt, Florig, Moulliard, J. E. Bell Pettigrew, Magnan, Wilbur Wright, Lanchester, Lilienthal, and Hankin.

D.E.D.A. (Detachable Data) System
R. Rorase Matther's Patents (provisionally protected). U.S. Patents applied for.

THE COMPASS

THE **Compass** is employed to set and steer a course as found from a map. Much thought and patient investigation has been devoted of late to the development of a suitable design of compass for aeroplane work.

With regard to the compass, the necessary precautions to be taken will be better understood if the principles and construction of the instrument are first examined. It consists of a flat circular card, the edge of which is divided into points, half points, and quarter points, and also into 360 degrees (see diagram and table, pp. 367-69). To the under side of the card are attached one or more light magnetic needles, and the whole is pivoted on a centre which in the best instruments consists of an iridium pivot bearing on an agate or sapphire cap. The card is enclosed in a cylindrical case, which for an aeroplane should be filled with liquid, and the case is hung on gimbals. The compass should be insulated as far as possible from shocks and vibration.

The point of the compass marked "N" does not point to the true north, but to the magnetic north. The angle between the two directions varies in different parts of the world at different times: in England it is at present about 15°. That is to say, the compass points in a direction 15° west of true north. This is called the **magnetic variation**.

Masses of iron or steel in close proximity to a compass will seriously affect its reading. Control levers are very often bad offenders in this respect, and if they are anywhere near the compass, should be made of non-magnetic material, such as special steel, duralumin, or bronze. It was recently mentioned that the steel clasp of a pilot's belt had a similarly bad effect. Errors due to fixed pieces of steel in the neighbourhood of the compass can be compensated for as follows:—

Semicircular Deviation.—This is of two kinds: (a) that due to any sub-permanent magnetism in the steel used in the construction of the aeroplane; (b) that due to magnetism induced by the earth in any vertical steel parts. To correct for (a) place the aeroplane on an even keel in the flying position, and with its longitudinal axis lying correct magnetic E. and W. If the compass now shows other than exactly E. or W. under the lubber line, place, on either side of the compass, a second magnet at right angles to the first

one, with its centre on a perpendicular from the centre of the compass, and its N. pole on that side towards which the N. pole of the compass card points. Move this magnet towards or from the compass until the position of the aeroplane as shown by the compass is exact magnetic E. and W. (Fig. X.). Then place the aeroplane with its long axis lying correct magnetic N. and S. Place a small permanent magnet either before or behind the compass at right angles to the meridian, with its N. pole on the side of the meridian to which the compass points, and move it towards or away from the compass until the latter shows correct magnetic N. and S. (Fig. X.).

These two adjustments are sufficient to correct any error due to permanent magnetisation of vertical steel portions of the

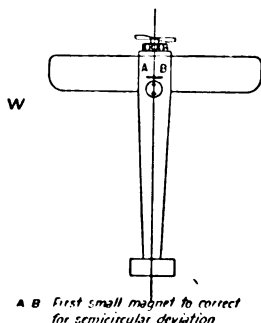


FIG. X.

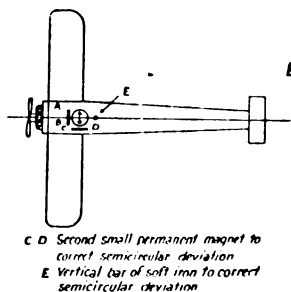


FIG. Y.

aeroplane. The next thing is to correct for (b) above. This is done with the aeroplane still in the magnetic E. and W. position: a vertical bar of soft iron is placed on the fore-and-aft line through the centre of the compass, on the opposite side of the compass to that towards which the N. on the card tends to point. The bar is moved to and from the compass until the aeroplane lies exact magnetic E. and W., as shown by the needle (Fig. Y.).

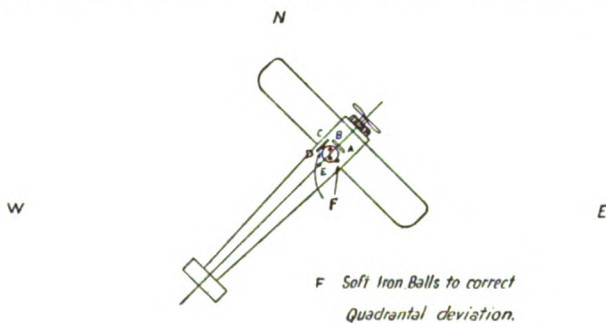
In aeroplane compasses, provision is usually made for holding the correcting magnets in the form of fore-and-aft, and athwartship holes, in the compass casing, so that the compass forms a complete unit.

When a compass has been thus corrected, although it will be practically exact on the points tested, there will be small errors on the other points. These errors are usually noted on a "deviation table" from observation, showing the error of the compass on the

eight principal points. The compass reading for any intermediate direction can be found by interpolation.

Testing Base.—It is convenient to lay out a base for compass adjustment in every aerodrome. It is set out (well away from buildings, etc.) by aid of a standard landing compass. By means of the prism and sighting vane, the eight principal bearings are marked out by pegs. Opposite pegs are joined up by four pieces of string, which should intersect at the centre of the base, if accurately laid out. The aeroplane is laid on these lines in turn, by sighting plumb lines, attached to the central points on the front and rear of the body of the aeroplane.

Quadrantal Deviation.—This is caused by magnetism induced by the earth in horizontal steel parts. It is not usual to adjust



S
FIG. Z.

an aeroplane for this, though probably it will be necessary in the case of all steel craft. To carry out this adjustment the aeroplane is placed with its longitudinal axis either N.E. and S.W., or N.W. and S.E., and soft iron balls are placed on each side of the compass on a line through its centre at right angles to the longitudinal axis of the aeroplane, and are moved toward or away from the compass until the indication of its needle is correct (Fig. Z.).

In addition to the above there is an error introduced when the aeroplane rolls. This can be corrected by placing a vertical magnet directly underneath the centre of the compass.

The Compass Adjuster.—The various corrections referred to in the preceding paragraphs are usually made by a professional compass adjuster, who is accustomed to similar work on aeroplanes or else on sea-going vessels, which likewise have to get their compasses adjusted from time to time.

STRUCTURAL DESIGN

Definitions of Terms—Load.—The external forces acting on a structural member.

Live Load.—A load which does not remain constant; a load that varies.

Stress.—The internal forces in a member resisting the action of a load: numerically equal to the load per unit of area.

Strain.—The change of form produced by the action of a load, measured as the ratio of the deformation to the original size of the member. Thus for a tensile load the strain is equal to the increase in length divided by the original length. *Hooke's law* states that the stress is proportional to the strain until the limit of elasticity is reached.

Elastic Limit.—The load at which a material subjected to its action no longer recovers its original shape on the load being removed.

Factor of Safety.—It is usual to design the parts of an aeroplane for the stresses induced in normal flight with a predetermined factor of safety. It is probably, to some extent, dependent upon the limiting velocity of the machine, the longitudinal moment of inertia, and the magnitude of the couple produced by the controls.

This factor of safety must also be large enough to cover the increased stresses due to the "flattening out" of an aeroplane after a nose-dive or other abnormal strain. It has been customary to select an average factor of safety in aircraft design as six, but this is more or less dependent on the type of machine, and in fact it ranges from five to fourteen for the individual parts on each machine. In a recent United States Army specification for hydro-aeroplanes, a factor of seven was required for materials subject to deterioration, and not less than six for other materials.

Modulus of Elasticity.—Since the stress is proportional to the strain, the ratio $\frac{\text{stress}}{\text{strain}}$ for any material for a particular kind of stress is constant, and is known as the Modulus of Elasticity. The constant for tensile stress is known as Young's Modulus, and is denoted by E; for shearing stress, as the modulus of transverse elasticity, or C; for bulk compression, as the modulus of bulk compressibility, or K.

Bending Moment.—The bending moment at any section of a beam is the algebraic sum of all the external forces acting on the beam on either side of the section, multiplied by their respective distances from the section.

Moment of Resistance.—The moment of resistance of a beam at any section is the combination of internal forces brought into play to resist the bending moment, and is numerically equal to the strength modulus Z multiplied by the greatest fibre stress at the section.

The following symbols will be employed :—

a = area of section in square inches.	k = least radius of gyration. l = length in inches.
E = Young's modulus of elasticity.	M = bending moment.
F_t = total tensile load.	n = factor of safety.
F_c = total compressive load.	P_e = Euler's limiting value $= \frac{\pi^2 EI}{l^2}$.
F_s = total shearing load.	P = direct compression.
f_t = tensile stress.	W = total lateral load, uniformly distributed.
f_c = crushing stress.	y = distance of extreme fibre from neutral axis.
f_s = shearing stress.	Z = modulus of section.
f_o = maximum compressive stress.	
g = acceleration of gravity.	
I = moment of inertia.	

Tensile Load.—

$$F_t = af_t.$$

Compressive Load.—Very short struts—

$$F_c = af_c.$$

Euler's formula for long struts—

$$\text{Fixed at one end, free at other—} \quad nF_c = \frac{\pi^2 EI}{4l^2}.$$

$$\text{Free at one end, guided at other—} \quad nF_c = \frac{\pi^2 EI}{l^2}.$$

$$\text{Fixed at one end, guided at other—} \quad nF_c = \frac{2\pi^2 EI}{l^2}.$$

$$\text{Fixed at both ends—} \quad nF_c = \frac{4\pi^2 EI}{l^2}.$$

$$\text{Rankine-Gordon formula for struts—} \quad nF_c = \frac{f_c a}{1 + c \frac{l^2}{k^2}}.$$

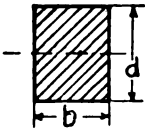
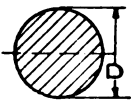
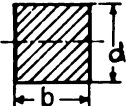
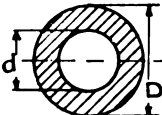
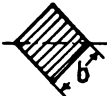
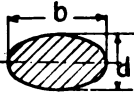
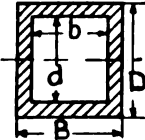
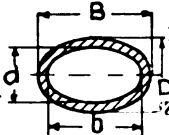
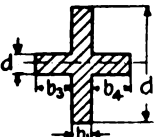
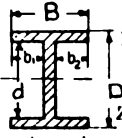
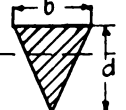
Where $f_c = 16$ for wrought iron, and 3.2 for timber,
 $c = .000028$ for wrought iron, and $.00033$ for timber.

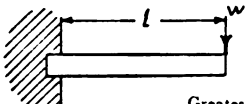
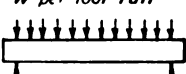
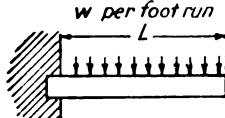
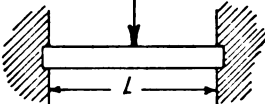
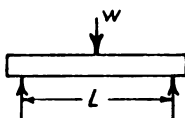
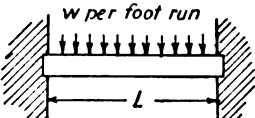
The above is for a strut fixed at both ends: c must be multiplied by 4 for a strut free at one end and guided at the other, or by 1.78 for a strut fixed at one end and hinged at the other.

Strut under a Lateral Bending Moment

$$f_c = \frac{Wl}{8z} \left(\frac{P_e - P}{P} \right) + \frac{P}{A},$$

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 $I = \frac{b^4}{12}$ $Z = \frac{1}{6} b^3$	 $I = \frac{\pi D^4}{64}$ $Z = \frac{\pi D^3}{32}$
 $I = \frac{bd^3}{12}$ $Z = \frac{1}{6} bd^2$	 $I = \frac{\pi}{64} (D^4 - d^4)$ $Z = \frac{\pi}{32} \frac{D^4 - d^4}{D}$
 $I = \frac{b^4}{12}$ $Z = \frac{\sqrt{2} b^3}{12}$	 $I = \frac{\pi}{64} bd^3$ $Z = \frac{\pi}{32} bd^2$
 $I = \frac{BD^3 - bd^3}{12}$ $Z = \frac{BD^3 - bd^3}{6D}$	 $I = \frac{\pi}{64} (BD^3 - bd^3)$ $Z = \frac{\pi}{32} \left(\frac{BD^3 - bd^3}{D} \right)$
 $b_2 = b_3 + b_4$ $I = \frac{b_1 d_1^3 + b_2 d_2^3}{12}$ $Z = \frac{b_1 d_1^3 + b_2 d_2^3}{6 d_1}$	 $b = b_1 + b_2$ $I = \frac{1}{12} (BD^3 - bd^3)$ $Z = \frac{1}{6} \left[\frac{BD^3 - bd^3}{D} \right]$
 $I = \frac{bh^3}{36}$ $Z = \frac{bh^2}{24}$	<i>Moments of Inertia of different Sections About Axis in Plane of Paper.</i>

 Greatest Bending Moment. Wl Greatest Deflection. $\frac{Wl^3}{3EI}$	 Greatest Bending Moment. $\frac{wl^2}{8}$ Greatest Deflection. $\frac{5wl^4}{384EI}$
 $\frac{wl^2}{2}$ $\frac{wl^4}{8EI}$	 $\frac{Wl}{8}$ $\frac{Wl^3}{192EI}$
 $\frac{Wl}{4}$ $\frac{Wl^3}{48EI}$	 $\frac{wl^2}{12}$ $\frac{wl^4}{384EI}$

In the above, the spar is considered to be freely supported at its ends. If, as is usually the case, the spar is continuous over its supports, l is often taken as nine-tenths of the actual span. However, this is not quite correct.

Crippling Loads upon Struts (R.A.F.)

$$\text{Crippling load in pounds} = \frac{FA}{1 + \frac{l^2}{k^2}}$$

Where $F = 5,600$ lbs. per sq. in. for spruce
 $= 6,250$ lbs. per sq. in. for ash,

$C =$ a constant depending upon the value of $\frac{l}{k}$.

The above formula applies to the compression stresses in the interplane struts, and to buckling loads upon the free lengths of wing spars.

Untapered Spruce Struts

(Hunsaker)

Struts, $1\frac{1}{4}$ in. $\times$ $1\frac{1}{4}$ in. and $1\frac{1}{2}$ in. $\times$ $\frac{1}{2}$ in. in section.

The Modulus of Elasticity "E" averaged 1,825,000 lbs. per sq. in.

Approximate Formulae

$$\text{When } L/K \text{ is greater than } 70 \quad \frac{P}{A} = \frac{.88 \times 10^6 E}{\left(\frac{L}{K}\right)^2}$$

$$\text{When } L/K \text{ is less than } 70 \quad \frac{P}{A} = 6500 - 46.5 \frac{L}{K}$$

Where I = moment of inertia of section about an axis parallel to the axes of pins in ends,

L = length of strut,

A = cross-sectional area,

K = radius of gyration defined as $\sqrt{\frac{I}{A}}$,

P = total load on strut.

Springs**Plate Springs.—**

$$W = n \cdot \frac{2bt^2}{f}$$

$$\delta = n \frac{Wl^3}{2Ebt^3}$$

Spiral Springs.—

$$W = \frac{\pi d^3}{8D} f$$

$$\delta = \frac{8Wl_1 D^2}{\pi C d^4}$$

Where

W = total load,

b = breadth of plates,

t = thickness of plates,

n = number of plates,

l = length between buckles,

l₁ = length of wire in spring,

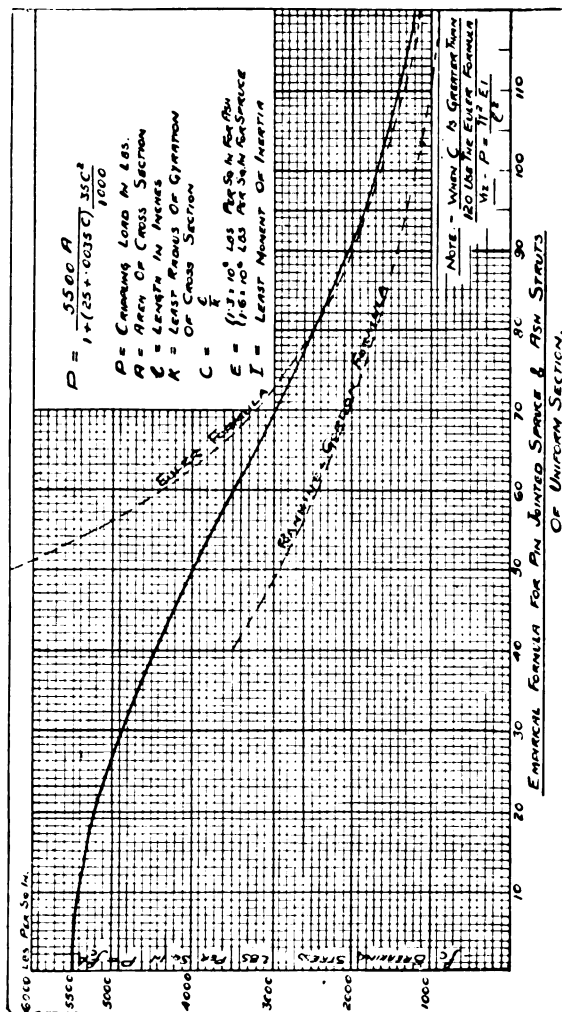
f = maximum fibre stress,

δ = deflection under load W,

d = diameter of wire,

D = diameter of coil.

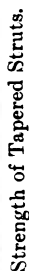
The lightest form of spiral spring is that made of thin circular tubing, which has almost twice the resilience of a solid wire spring of the same weight. Moreover, the resilience of any given material is greater in spiral spring form than in any other form, for the same weight.

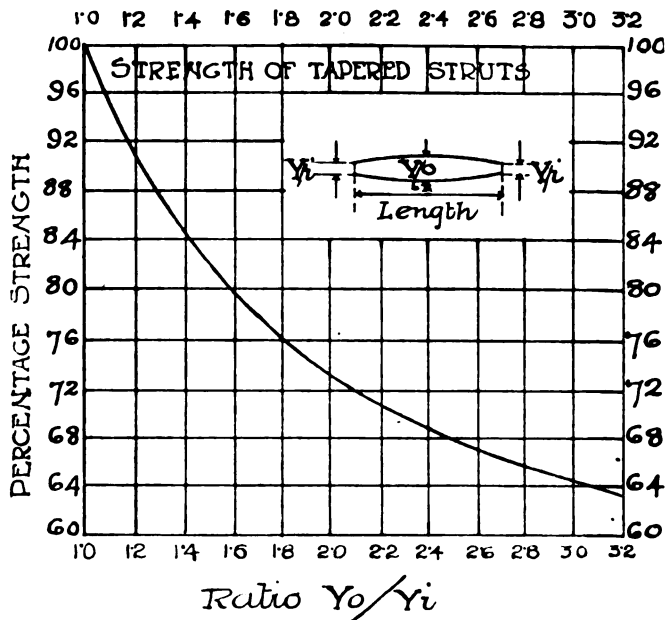


Strength of Tapered Struts.

L.E.D.A. (Detachable Data) System
 R. Borlase Matheson Patents provisionally protected U.S. Patents applied for.

III



**Shafts**

$$T = \frac{\pi}{16} d^3 f \text{ (solid shaft).}$$

$$T = \frac{\pi}{16} \frac{d^4 - d_1^4}{d} f \text{ (hollow shaft).}$$

Where

T = torque applied to shaft,
 d = external diameter of shaft,
 d_1 = internal diameter of shaft,
 f = extreme stress.

Thin Cylinders, Pipes

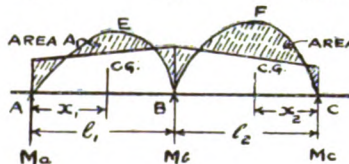
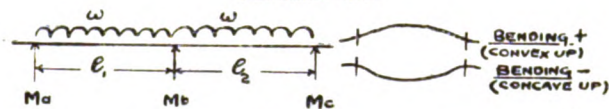
Greatest stress is given by $f = \frac{pd}{2t}$.

Where

p = internal pressure, lbs. per square inch,
 d = diameter of pipe,
 t = thickness of pipe.

THEOREM OF THREE MOMENTS

GENERAL CASE



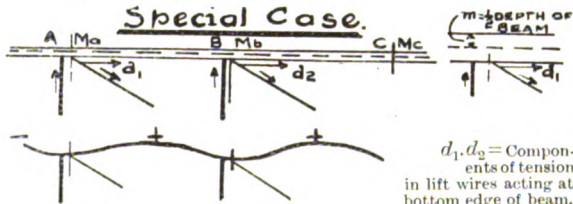
A_1 = Area of B.M. diagram
A.E.B.A.

A_2 = Area of B.M. diagram
B.F.C.B.

$$\frac{A_1 x_1}{l_1} + \frac{A_2 x_2}{l_2} + \frac{1}{6} l_1 M_a + \frac{1}{3} (l_1 + l_2) M_b + \frac{1}{6} l_2 M_c = 0,$$

or,
$$\frac{6A_1 x_1}{l_1} + \frac{6A_2 x_2}{l_2} + l_1 M_a + 2(l_1 + l_2) M_b + l_2 M_c = 0.$$

Special Case.



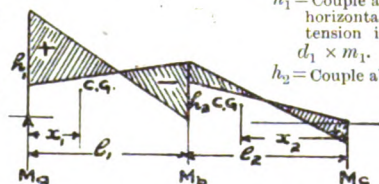
d_1, d_2 = Components of tension in lift wires acting at bottom edge of beam.

$$A_1 = h_1 \times \frac{l_1}{2}$$

$$x_1 = \frac{1}{3} l_1$$

$$A_2 = h_2 \times \frac{l_2}{2}$$

$$x_2 = \frac{2}{3} l_2$$



h_1 = Couple about point A of the horizontal component of the tension in the lift wire = $d_1 \times m_1$.

h_2 = Couple about point B of the horizontal component of the tension in the lift wire = $d_2 m_2$ where $m = \frac{1}{2}$ depth of beam.

A₁ AREA OF FIGURE.

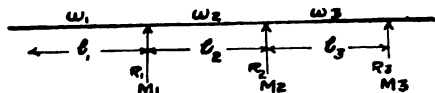
x_1 = Distance from M_a of C.G. of Figure A₁

x_2 = " " " " M_c " " " " A₂

$$\frac{6A_1 x_1}{l_1} + \frac{6A_2 x_2}{l_2} + l_1 M_a + 2(l_1 + l_2) M_b + l_2 M_c = 0,$$

$$\text{or, } \frac{6h_1l_1 + l_1}{2 \times 3 \times l_1} + \frac{6h_2l_2 + 2l_2}{2 \times 3 \times l_2} + l_1M_a + 2(l_1 + l_2)M_b + l_2M_c = 0,$$

$$\text{or, } h_1l_1 + 2h_2l_2 + l_2M_a + 2(l_1 + l_2)M_b + l_2M_c = 0.$$



w_1, w_2, w_3 = Loading per foot run in lbs.

l_1, l_2, l_3 = Distance between points of support.

M_1, M_2, M_3 = Bending moments.

$$M_1 = \frac{1}{4}w_1l_1^2.$$

$$M_2 = (M_1 \times l_2) = 2M_2(l_2 + l_3) + (M_3 \times l_3) = \frac{w_2(l_2^3 + l_3^3)}{4}$$

when $w_3 = w_2 = w$.

REACTION AT POINTS OF SUPPORT

Let R_1, R_2, R_3 = Shearing force.

$$R_1l = \frac{2}{3}w_1l,$$

$$R_1r = \frac{M_1 - M_2}{l_2} + \frac{w_2l_2}{2},$$

$$R_2l = \frac{M_2 - M_1}{l_2} - \frac{w_2l_2}{2},$$

$$R_2r = \frac{M_2 - M_3}{l_3} - \frac{w_3l_3}{2}, \text{ etc.}$$

APPROXIMATION OF THEOREM OF THREE MOMENTS



$$M_2 = \frac{\frac{w_1l_1^3}{12} + \frac{w_2l_2^3}{12}}{l_1 + l_2},$$

$$M_a = \frac{w_1l_1^2}{8} - \frac{M_1 + M_2}{2}.$$

STRENGTH AND WEIGHT OF MATERIALS

Note.—“Transverse strength” = $\frac{\text{Modulus of rupture}}{6}$

METALS

	Specific Gravity.	Weight of a Cubic Foot.	Weight of a Cubic Inch.	Ultimate Tensile Strength per Square Inch.	Crushing Weight per Square Inch.		Transverse Strength.	
					Lbs.	Tons.	Tons.	Tons.
Aluminium, sheet	2.67	166.6	.096	...	...	...	...	...
“ cast	2.56	159.8	.092	...	...	...	...	...
Copper bolts	8.85	552.4	.318	17.0	...	...	...	...
“ cast	8.607	537.3	.31	8.4	...	...	...	...
“ sheet	8.78	548.1	.316	13.4	...	...	...	...
“ wire	8.9	555.0	.32	26.0	...	...	...	...
Iron, cast, from	7.0	437.0	.252	6.0	...	36.0	...	2.0
“ to	7.6	474.4	.273	13.0	...	64.0	...	3.4
“ average	7.23	451.0	.26	7.3	...	48.0	...	2.6
“ wrought, from	7.6	474.4	.273	16.0	...	16.0	...	3.0
“ to	7.8	486.9	.281	29.0	...	18.0	...	5.5
“ average	7.78	485.6	.28	22.0	...	16.9	...	3.8
“ wire	...	...	...	40.0	...	...	...	...
Mercury	13.59	848.75	.489	...	...	...	...	...

STRENGTH AND WEIGHT OF MATERIALS—Continued

METALS—Continued

	Specific Gravity.	Weight of a Cubic Foot.	Weight of a Cubic Inch.	Ultimate Tensile Strength per Square Inch.	Crushing Weight per Square Inch.	Transverse Strength.
Steel—						
Mild steel plate and bar,	8.0	Lbs. 499.0	Lbs. .288	Lbs. 35.0	Lbs. ...	Lbs. ...
R.A.F. No. 3a	8.0	499.0	.288			
Steel for tie rods, R.A.F.	"	"	"	60 to 70		
No. 97a	"	"	"			
Axle steel, R.A.F. No. 43	"	"	"	45 annealed		
Forging and stamping steel,	"	"	"	90 hardened		
R.A.F. No. 29a	"	"	"	40.0		
Mild steel tube.	"	455.1	.262	30.0	6.7	
Tin, cast	7.291	437.0	.252	2.0		
Zinc, cast	7.0			3.3		

ALLOYS

	Specific Gravity.	Weight of a Cubic Foot.	Weight of a Cubic Inch.	Ultimate Tensile Strength per Square Inch.	Crushing Weight per Square Inch.	Transverse Strength.
Aluman	2.95	Lbs. 184.0	Lbs. .106	Lbs. 42,700	Lbs. ...	Lbs. ...
Aluminium bronze (90 per cent. copper)	7.68	481.0	.276	92,400	129,000	
Chrome aluminium	2.95	184.0	.106	64,000		
Duralumin	2.85	178.0	.103	56,000		

MATERIALS

539.9

Magnalium	2.44	152.9	.088	{ 41,000 to } { 64,000 }	...
Nickel aluminium	2.95	184.0	.106	57,000	...
Partinim	2.85	178.0	.103	21,300	...
Brass, cast	8.4	524.37	.3	18,000	...
" sheet	8.44	526.86	.301	27,000	...
" wire	8.54	533.109	.307	49,000	...
Gold (standard)	17.724	1,106.42	.638	...	...
(Gun-metal, 10 copper, 1 tin)	8.464	528.36	.306	46,000	...
White metal (Babbett)	7.31	456.32	.263	...	...

MISCELLANEOUS SUBSTANCES

Glass, plate	2.7	170	Lbs.	Lbs.	Lbs.
Glue	...	...	.10	2,700	...
Gutta-percha	0.98	61	.035	500-750	...
Hemp rope	1.3	84	...	...	...
Horn	...	...	...	6,800-17,000	...
Indiarubber	0.93	58	.034	9,000	...
Leather	...	...	...	330	...
Plaster of Paris	0.81	50	.029	3,000-5,000	...
Raw hide	...	...	...	...	...
Silk	1.62	101	.051	12,000	...
Whalebone	...	...	...	35,000-62,000	...
				7,600	...

MODULI OF ELASTICITY

(Millions of Pounds per Square Inch)

Material.	E.	C.	K.
Aluminium, cast - -	12.0	3.4 to 4.8	...
„ sheet - -	13.0		
„ wire - -	19.0		
„ bronze (90 per cent. Al, 10 per cent. Cu)	18.0		
Brass, cast - -	9.0	5.0 to 5.5	15.3
„ rolled - -	12.5		
„ wire - -	14.2		
Copper, cast - -	12.0	5.6 to 6.7	17.1 to 24.4
„ rolled - -	15.0		
„ wrought - -	16.0		
„ wire - -	17.0		
Delta-metal, cast - -	12.0	... 5.25	14.4
„ rolled - -	13.0		
Gold, drawn - -	12.0	4.0 to 5.6	...
Gun-metal - -	13.5	3.7	...
Iron, cast - -	17.0	5.0 to 7.6	14.1
„ wrought, bars - -	29.0	10.5	21.0
„ „ plates - -	26.0	9.5	
„ „ wire - -	25.0	...	
Lead - -	0.72	0.27	5.3
Magnalium - -	10.2	...	...
Phosphor bronze - -	14.0	5.3	...
Platinum - -	24.0	8.9 to 9.4	...
Silver - -	11.0	3.8	...
Steel, mild - -	30.0	11.0	21.6 to 26.7
„ bars - -	29.42	13.0	
„ cast, tempered - -	36.0	14.0	
„ cast, untempered - -	30.0	12.0	
„ tool - -	40.0	...	
„ wire - -	27.0	...	
„ piano wire - -	32.0	...	
Tin - -	4.6	2.2	...
Zinc - -	13.68	5.1 to 5.4	...
Indiarubber - -	Varies	...	...
Silk - -	1.3	...	...
Slate - -	13.0	3.2	...
Leather - -	.025	...	...
Glass (plate) - -	8.0	3.3 to 3.9	5.8

MODULI OF ELASTICITY—Continued

Material.	E.	C.	K.
Ice - - - -	8.5	...	...
Wood - - - -	...	0.1 to 0.17	...
Water - - - -	...	...	0.32
Alcohol - - - -	...	...	0.162
Ether - - - -	...	...	0.115
Carbon bisulphide - - - -	...	...	0.232
Glycerine - - - -	...	...	0.585
Petroleum - - - -	...	...	0.211
Mercury - - - -	...	...	7.850

 PHYSICAL AND MECHANICAL PROPERTIES OF
BRASS, STEEL, AND ALUMINIUM

Property.	Brass.	Steel.	Aluminium.
Melting point, ° C. - -	950	1,400	655
Melting point, ° F. - -	1,740	2,550	1,210
Annealing point, ° C. - -	500	760	400-480
Annealing point, ° F. - -	868	1,400	750-900
Specific heat (water = 1) -	0.094	0.117	0.212
Thermal conductivity (silver = 100)	23.8	11.7	31.3
Coefficient of linear expansion, per ° C.	0.0000189	0.0000120	0.0000234
Coefficient of linear expansion, per ° F.	0.0000105	0.0000067	0.0000130
Specific gravity, cast - -	8.10	7.73	2.60
Specific gravity, rolled - -	8.62	7.74	2.67
Weight in lbs. per cub. in., cast	0.294	0.280	0.0944
Weight in lbs. per cub. in., rolled	0.313	0.281	0.0969
Tensile strength in lbs. per sq. in., cast	18,000	70,000	13,000
Tensile strength in lbs. per sq. in., rolled	22,400	115,000	20,000
Elastic limit as per cent. of tensile strength	38	66	70
Modulus of elasticity in lbs. per sq. in.	9,200,000	30,000,000	9,000,000

WEIGHT AND VOLUME OF WATER AT DIFFERENT TEMPERATURES

Temperature, ° F.	Relative Volume.	Weight per Cubic Foot (Lbs.).	Weight per Gallon (Lbs.).
32.0	1.00000	62.418	10.0101
35.0	0.99993	62.422	10.0103
39.1	0.99989	62.425	10.0112
40.0	0.99989	62.425	10.0112
45.0	0.99993	62.422	10.0103
46.0	1.00000	62.418	10.0101
50.0	1.00015	62.409	10.0087
52.3	1.00029	62.400	10.0072
55	1.00038	62.394	10.0063
60	1.00074	62.392	10.0053
62	1.00101	62.355	10.0000
65	1.00119	62.344	9.9982
70	1.00160	62.313	9.9933
75	1.00239	62.275	9.9871
80	1.00299	62.232	9.980
85	1.00379	62.182	9.972
90	1.00459	62.133	9.964
95	1.00554	62.074	9.955
100	1.00639	62.022	9.947
105	1.00739	61.960	9.937
110	1.00889	61.868	9.922
115	1.00989	61.807	9.913
120	1.01139	61.715	9.897
125	1.01239	61.654	9.887
130	1.01390	61.563	9.873
135	1.01539	61.472	9.859
140	1.01690	61.381	9.844
145	1.01839	61.291	9.829
150	1.01989	61.201	9.815
155	1.02164	61.096	9.799
160	1.02340	60.991	9.781
165	1.02589	60.843	9.757
170	1.02690	60.783	9.748
175	1.02906	60.665	9.728
180	1.03100	60.548	9.711
185	1.03300	60.430	9.691
190	1.03500	60.314	9.672
195	1.03700	60.198	9.654

D.E.D.A. (Detachable Data) System
 R. Barlow Matthews' Patents (provisionally protected). U.S. Patents applied for.

WEIGHT AND VOLUME OF WATER AT DIFFERENT TEMPERATURES—Continued

Temperature, F.	Relative Volume.	Weight per Cubic Foot (Lbs.).	Weight per Gallon (Lbs.).
200	1.03889	60.081	9.635
205	1.04140	59.930	9.611
210	1.04340	59.820	9.594
212	1.04660	59.640	9.565
250	1.06243	58.750	9.422
300	1.09563	56.970	9.136
400	1.15056	54.250	8.700
500	1.22005	51.160	8.240

THE ATMOSPHERE

551.51

The atmosphere consists mainly of a mixture of two gases, oxygen and nitrogen, in the proportion by volume: oxygen, 20.84, say 21 per cent., and nitrogen, 79.16, say 79 per cent.; or, by weight, oxygen, 23.15, say 23 per cent., and nitrogen, 76.85, say 77 per cent. There is also 0.03 to 0.04 per cent., by volume, of carbon dioxide, and in addition traces of neon and helium (15 and 5 parts in one million volumes respectively). The amount of water vapour in suspension varies with the temperature, being greater when the latter is high.

One kg. } of oxygen is contained in $\frac{100}{23} = 4.35$ kg. of air.
 One lb. } of oxygen is contained in $\frac{100}{23} = 4.35$ lbs. of air.

One litre } of oxygen is contained in $\frac{100}{21} = 4.8$ litres of air.
 One cub. ft. } of oxygen is contained in $\frac{100}{21} = 4.8$ cub. ft. of air.

One lb. of dry air at normal temperature and pressure occupies 12.387 cub. ft.

One cub. ft. of dry air at N.T.P. weighs 0.08073 lb.

1,000 cub. ft. of dry air at N.T.P. weighs 80 lbs.

Standard atmosphere:—

1.0333 kg. per sq. cm. = 760 mm. (29.922 in. of mercury at 0° C).

14.704 lbs. per sq. in. = 29.922 in. of mercury at 32° F. = 30 in. at 57.8° F.

The specific gravity of air is 14·44, hydrogen being taken as unity.

Air at normal pressure, temp. 62° F., weighs 532·5 grains per cubic foot, which is equivalent to 13·15 cub. ft. per lb. (See table a few pages further on.)

The atmosphere extends appreciably to at least 50 miles from the earth's surface, and probably in an extremely rarefied condition to 300 miles. At this height its density is computed to be only one two-millionth as great as at sea level. One half its total mass is below 15,000 ft. (say 3 miles). This is higher than the highest permanent habitations of man. Mountain climbers and balloonists have attained greater altitudes. Mont Blanc is 15,782 ft. (about 3 miles). Suring and Berson established a height record of 10,800 metres (about 6½ miles) in a spherical balloon in 1901. However, above a level of 5 miles the air is too greatly rarefied to support life. A little above the 10 mile level the air is only one-eighth as dense as at sea level. Naturally the greatest heights attainable by an aeroplane are much less than is the case with a balloon. Lieut. Oelrich, in 1914, reached a height of 25,750 ft. (8,150 metres, or nearly 5 miles). Recently, unofficial height records have been made of over 28,000 ft. (nearly 6 miles). It seems probable that the limit for aeroplane flight is only a few thousand feet higher than this, since the rarefaction of the air becomes too great for the effective operation of the engines; at any rate, as they are designed at present.

By means of the sounding balloon the air has been explored to a height of 21·8 miles. A sounding balloon is a free aerostat, arranged to carry recording instruments. It is usually constructed of india-rubber, and when launched, is inflated to less than its full capacity. As it rises to regions of diminished air pressure it gradually expands, and finally bursts at an elevation approximately determined in advance, and then parachutes to the ground. Attached to the apparatus is a card offering the finder a reward for its return.

Another device employed by meteorologists in investigations of the atmosphere of the earth is the pilot-balloon. This is a free balloon unprovided with instruments. Its motion in the air is followed by means of a theodolite, and it serves to show the speed and direction of the wind at different levels. An altitude of 24·2 miles has been measured in this way.

The pressure of the atmosphere at sea level is 14·7 lbs. to the square inch, or 2,116 lbs. to the square foot, at 32° F.; it varies with the height above sea level, as shown in the following tables.

The temperature of the atmosphere decreases on an average about 1·75° C. (3·66° F.) per 1,000 ft. above the earth's surface. On any actual day the rate of fall varies very irregularly, according to atmospheric conditions. Occasionally, what is known as inversion of temperature occurs, when in places the temperature

actually rises with increase of altitude. Mr Glaisher, in his balloon ascents, found unequal variations on passing through different air strata, once finding a comparatively warm current at 14,000 ft. ; an alternation of warm and cold currents was sometimes met with. On an average, however, the temperature decreases much as given above, until, at an altitude of something over 25,000 ft., it becomes practically constant.

The reason for the temperature being higher at points nearer the earth is the transmission of sun's rays in the form of vibrations in the ether, and on reaching the earth's surface these are absorbed and converted into heat waves. The air is then warmed by contact with the warm ground. Air currents are thus set up which distribute the heat through the atmosphere.

The pressure of the air is intimately related to the wind, which is a weather element of much moment. Other elements of weather also bear typical relations to the distribution of atmospheric pressure. Hence barometric readings, taken simultaneously at a number of places, are of the utmost importance in the forecasting of the weather.

The weather with which aviators are concerned may be said to extend upward 7 or 8 miles ; i.e., to the level of the higher clouds or, in meteorological language, the troposphere. The region above the troposphere is known as the stratosphere or isothermal layer.

The following table is given by Berson :—

Altitude in Feet.	Mean Temperature. ° F.	Decrease per 1,000 Feet.	Altitude in Feet.	Mean Temperature. ° F.	Decrease per 1,000 Feet.
0	50	...	16,000	3½	3
2,000	45	2½	17,000	0	3½
4,000	40	2½	18,000	- 4	4
6,000	34	3	20,000	- 12	4
8,000	28	3	22,000	- 20	4
10,000	22	3	24,000	- 28	4
12,000	15½	3	26,000	- 36	4
14,000	9½	3	28,000	- 44	4

The **weight** of dry air is given by—

$$W = 2.709 \frac{P}{T}$$

Where W = weight of 1 cub. ft. of air in lbs.,

P = pressure in lbs. per square inch (including atmosphere).

T = absolute temperature (= ° F. + 461).

WEIGHT IN LBS. PER CUBIC FOOT OF DRY AIR AT
DIFFERENT PRESSURES AND TEMPERATURES

Temperature, °F.	-40	-20	0	20	40	60	80	100
Barometer Reading, In.								
30.5	.0964	.0920	.0880	.0844	.0810	.0779	.0750	.0723
30	.0948	.0905	.0866	.0830	.0797	.0766	.0737	.0711
29.5	.0932	.0890	.0852	.0816	.0784	.0753	.0725	.0700
29	.0916	.0875	.0837	.0802	.0770	.0740	.0713	.0688
28.5	.0901	.0860	.0823	.0788	.0757	.0728	.0701	.0676
28	.0885	.0845	.0808	.0774	.0744	.0715	.0688	.0664
27.5	.0869	.0829	.0793	.0760	.0730	.0702	.0676	.0652
27	.0853	.0815	.0779	.0747	.0717	.0689	.0664	.0641
26	.0822	.0784	.0750	.0719	.0691	.0664	.0639	.0617
25	.0790	.0754	.0722	.0691	.0664	.0638	.0615	.0593
24	.0759	.0724	.0693	.0664	.0638	.0613	.0590	.0569
22	.0695	.0663	.0635	.0608	.0584	.0562	.0541	.0521
20	.0632	.0603	.0577	.0553	.0531	.0511	.0492	.0474
18	.0569	.0543	.0520	.0498	.0478	.0460	.0443	.0427
16	.0506	.0483	.0462	.0443	.0425	.0409	.0394	.0380
14	.0443	.0423	.0404	.0388	.0372	.0358	.0345	.0332
12	.0379	.0362	.0346	.0332	.0319	.0306	.0295	.0284
10	.0316	.0302	.0289	.0277	.0266	.0255	.0246	.0237
5	.0158	.0151	.0145	.0139	.0133	.0128	.0123	.0119

VOLUME OF ONE POUND OF DRY AIR IN CUBIC FEET

Barometer Reading, Inches.	Cubic Feet.	Barometer Reading, Inches.	Cubic Feet.
30	12.84	17.46	19.94
28.91	13.23	16.76	20.62
27.86	13.64	16.08	21.32
26.83	14.06	15.43	22.05
25.84	14.50	14.80	22.81
24.90	14.95	14.19	23.61
23.95	15.42	13.60	24.44
23.04	15.91	13.03	25.31
22.17	16.42	12.48	26.21
21.32	16.95	11.95	27.15
20.49	17.51	11.43	28.14
19.70	18.08	10.94	29.17
18.93	18.68	8.7	35.08
18.18	19.30		

The weight of one cubic foot of air in pounds is the reciprocal of the figure given for the cubic feet in the above table.

BEHAVIOUR OF WINDS

Aviators must always be more or less at the mercy of the wind, but less as they gain experience in meeting the ever-changing wind conditions imposed upon them in practice.

Wind is air in sensible motion, and is produced by differences of pressure, which are themselves attributable to changes of temperature.

Generally, the velocity of the wind follows closely upon the temperature. Before sunrise it falls to a minimum, reaching, between 2 and 4 A.M., an almost dead calm, while between noon and 2 P.M. it rises to a maximum.

The wind is neither regular in direction nor in velocity, but blows more or less in gusts with varying currents and eddies set up by obstructions and temperature differences.

The variations of speed and of direction do not take place simultaneously, although they take place at similar intervals of time. Wilbur Wright states that a gust may come on so suddenly that the front of the machine is thrown up before the back part is acted on at all. The same authority is responsible for the statement that "it is an almost universal rule that gusts come on with a rising trend and die out with a descending trend."

These sudden variations of speed are much more marked in the presence of obstructions, and become smaller with increase of height above the ground.

Masses of air are constantly changing places, cold air descending to the earth's surface, spreading itself out, becoming warm, and then ascending in streams or currents in other places.

Ascending streams of air may be any distance apart, from $\frac{1}{4}$ mile up to 20 miles, and may rise as fast as from 6 to 10 miles per hour. They are in thin sheets or long walls, and may be approximately straight or of irregular curvature. The action is continuously taking place over both sea and land, and is rendered visible in the glassy streaks or zones that are seen at sea. These calm portions are caused by the air meeting from both sides, and ascending in practically a straight line from the surface of the water. On each side of a streak the wind will be found to be blowing in opposite directions. Under some circumstances the presence of these

ascending streams is made visible by the formation of cumulus clouds; it is now agreed that a cloud of this kind is merely the cap of a column of rising air. Hence care should be exercised when the sky contains a large number of isolated cumulus clouds, since there will probably be descending streams in the clear portions, and ascending ones below the clouds.

Within a thundercloud the vertical motion is very violent, and "the vertical currents are sometimes comparable with the strongest surface winds" (Sir W. Napier Shaw).

Over the sea the velocity of the wind is much greater than over the land. The difference is very marked between a point on the shore and a headland jutting into the sea or a lake. The average velocity of the wind in the United States all the year round at a height of 50 ft. above the ground is about 11 miles an hour (Thomas Russell).

In 1876-7 the mean of 650 daily observations over the five great oceans showed the average wind velocity to be 17 miles per hour. On land during the same period the average velocity was 12½ miles per hour.

Obstructions such as sea cliffs or the sides of quarries give rise to upward currents. Small obstructions, such as houses or groups of trees, will also start them, but at sea and on large open plains there does not appear to be any definite reason why a vertical current should commence at one place rather than at another.

Under some circumstances the wind to be expected can be predicted with a considerable degree of accuracy. An estimate of wind velocity can be got at any time between 8 A.M. and 8 P.M. in answer to a prepaid reply telegram to the Meteorological Office.

On the sea coast there is usually a light breeze from the sea in the morning, which increases towards midday, and dies to a calm in the evening. During the night the wind blows from the land in a similar fashion. These coastal winds are accompanied by opposite movements of the air in strata about 500 to 1,000 ft. high, and are rarely felt for more than 20 miles from the coast.

From the calms about the Equator to the parallel of 28° in the northern hemisphere, and to the parallel of 25° in the southern hemisphere, steady winds prevail through about two-thirds of the earth's circumference; they are known as the trade winds, and blow respectively from the north-east and the south-west.

In India the *monsoons* blow from the north-east from October to March, and from the south-west from April to September.

Within the temperate latitudes the winds are of uncertain occurrence and duration, but are more usually from the westward.

The most dangerous wind met with in England is that known as the "line squall," so called because it advances with a line front like a tidal wave, usually lying S.W. and N.E., and advancing from N.W. to S.E. The signs of this wind are—

1. A sudden fall of temperature.
2. A veer of the wind.
3. A rise of pressure.
4. A squall of rain, hail, or snow.

The squall itself is accompanied by thunder and lightning, and must inevitably prove fatal to any aeroplane or dirigible encountered.

The above is sufficient to show that the numerous problems presented by the behaviour of the wind are of a very complex character. However, the aviator is working out daily a practical solution. Though he may appear to be taking his ease while in the air, he is really responding to every trick of the wind more or less automatically, according to his degree of skill. The management of his machine becomes to him a matter of course, and his skill may be gauged by the ease with which it is accomplished.

At the first Rheims aviation meeting the majority of the competitors did not attempt to fly unless the velocity of the wind was less than 7 miles an hour. Several could start with a wind velocity of a little over 10 miles, and when started could fly in a wind of about 20 miles. At the Hendon meeting of Easter 1912 one short flight was made in a wind varying from almost nothing to 50 miles an hour, while several were made in a gusty 40-mile breeze. Nowadays an experienced aviator with a powerful aeroplane can fly in anything short of a strong gale.

Storm and Wind Signals

The **South Cone** is point downwards, and is hoisted if a gale is expected from between E. and S.E., which will veer round by S. to S.W. or N.W.

The **North Cone** is point upwards, and is hoisted if gales from N.W. round by N. to N.E. or S.E. are probable.

By night a signal of lamps in the appropriate positions is hoisted. The signal is kept flying for forty-eight hours from the time the message was issued from the Meteorological Office. It may be noticed that a gale from the E. is more likely to back to the N. than to shift to the S.

SEA DISTURBANCE SCALE

(Provisional)

Scale.	Description.	Height of Waves in Feet from Crest to Trough.	Condition of Surface.
0	Calm - - -	...	Glassy.
1	Smooth - - -	...	Rippled.
2			Rocks buoy or
3			small boat.
4	Slight to moderate	Under 5 ft.	Furrowed.
5	Rough to very rough	5 to 10 ft.	Much disturbed ;
6			deeply furrowed.
7	High to very high	11 to 15 ft.	Rollers with steep fronts.
8		16 to 35 ft.	
9	Phenomenal-	36 ft. and above	Precipitous ;
10			towering.

BEAUFORT NOTATION

<i>b</i>	blue sky (not more than a quarter of the sky covered).	<i>o</i>	overcast sky.
<i>bc</i>	sky partly cloudy (one-half covered).	<i>p</i>	passing showers.
<i>c</i>	generally cloudy (three-quarters covered).	<i>q</i>	squalls.
<i>d</i>	drizzle, or fine rain.	<i>r</i>	rain.
<i>e</i>	wet air without rain falling, a copious deposit of water on trees, buildings, or rigging.	<i>rs</i>	sleet, i.e., rain and snow together.
<i>f</i>	fog.	<i>s</i>	snow.
<i>g</i>	gloom.	<i>t</i>	thunder.
<i>h</i>	hail.	<i>u</i>	ugly, threatening sky.
<i>l</i>	lightning.	<i>v</i>	unusual visibility. The horizon or distant hills unusually clear.
<i>m</i>	mist.	<i>w</i>	dew.
		<i>x</i>	hoar frost.
		<i>z</i>	dust haze; the turbid atmosphere of dry weather.

WIND VELOCITY AT VARIOUS STATIONS DURING 1908

(Abstracted from a Meteorological Office Report)

Hours during which the velocity was within the given limits

WIND VELOCITY

551.511.4

Beaufort Number.	Mean Velocity, Miles per Hour.	Aber-deen.	Armagh.	Brighton.	Dover.	Dublin.	Fal-mouth.	Fleet-wood.	Glasgow.	Holyhead.	Kew.	Kings-town.
0	0	Hours. 19	Hours. 279	Hours. 67	Hours. 336	Hours. 655	Hours. 5	Hours. 1	Hours. 23	Hours. 9	Hours. 44	Hours. 176
1	1-3	1,249	3,094	1,530	1,258	1,804	1,278	554	1,667	752	2,018	702
2	4-7	3,481	3,126	2,686	1,562	3,271	3,161	1,844	3,280	1,652	3,099	1,386
3	8-12	2,582	1,598	2,120	1,953	1,755	2,456	2,465	2,599	1,996	2,245	1,878
4	13-18	1,092	588	897	1,779	875	1,272	1,932	987	2,014	1,147	1,871
5	19-24	281	78	225	1,085	202	509	1,030	166	1,361	191	1,031
6	25-30	58	9	44	529	22	100	587	26	655	40	642
7	31-38	20	5	2	123	6	3	261	1	270	...	256
8	39-46	2	...	...	10	...	...	83	...	62	...	46
9	47-54	...	...	...	...	...	...	21	...	13	...	2
10	55-63	...	...	...	...	...	...	2	...	...	...	...
11	64-75	...	...	...	...	...	...	...	...	...	...	...
12	above 75	...	...	...	...	...	...	...	...	...	...	...
Total hours recorded		8,764	8,777	8,239	8,635	8,590	8,784	8,780	8,769	8,784	8,784	8,743
" " unrecorded		...	7	545	149	194	...	4	25	...	...	41

Gales

8

9

10

11

12

Gales

Wind at High Levels.—Winds near the ground are checked by friction with the surface of the earth, in the same way that water near the bank of a river is held back by friction with the banks, but runs freely in mid-stream. There is usually a marked and gradual increase in the velocity of the wind up to 3,000 ft. Not only is there a change of velocity with height, but also a change in direction—normally clockwise. This veering of the wind occurs both in cyclonic and anti-cyclonic weather. In planning a long cross-country flight, an aviator must so set his course, as to allow for the velocity and direction of the wind at the height at which it is proposed to make the journey. Above 3,000 ft., the changes of direction are uncertain. Backing is more likely with a northerly wind, or veering with a southerly wind, at great heights.

Height in ft.	500	1,000	2,000	3,000	4,000	5,000	7,500	10,000
Change in degree	5	10	15	18	20	21	23.5	25
No. of times velocity of wind near ground	1.1	1.4	1.9	1.9	1.9	2	2.1	2.2

As far as England is concerned, the following rules are given by Mr W. H. Dines in a paper to the Aeronautical Society:—

“Almost every wind that blows at an inland station will be found to be stronger at a few hundred feet above the surface. As a general rule it will be found that if you face the surface wind, the wind above will come somewhat from your right hand. Suppose a balloon is at a height of 2,000 ft., an east wind is not likely to increase much in strength above this height, but a south-west or west wind is likely to do so. A south-east wind on the surface is fairly certain to turn to a south and then to a south-west wind at a moderate elevation, and a north wind may draw into a north-west, but it is not likely to do so. As a rule, for winds other than north, a change of two points of the compass in direction, and a doubling of the velocity, may be expected between the surface and 3,000 ft., excepting during a hot sunny day in spring and summer. On such days a general mixing of the air by convection currents tends to equalise the different strata, and the velocity at the surface will not be greatly less than above. At night calm mostly prevails in the lower strata if the sky is clear, and this is particularly the case on frosty nights, and even days, too, in the winter. But there is no rule hardly without an exception, and I have met with exceptions to all the above rules.”

WIND FORCE

551.511.5

Very often an easterly or north-easterly wind may be strong near the ground, and fall off very rapidly above 800 to 1,600 ft.

The wind velocity and pressure increase in the higher zones of the atmosphere, up to two or three times the surface velocity, or sometimes even more.

The following formulæ have been suggested :—

$$P = p \sqrt{\frac{H+72}{h+27}} \quad (\text{Stevenson.})$$

$$v = 1347 \cdot 4 \sqrt{\frac{H-h}{h}} \quad (\text{Kempster.})$$

Where P = the pressure at height H .
 p = the pressure at height h .
 v = the velocity at different zones.

According to Sir W. Napier Shaw, a likely formula for the increase of velocity with height above the ground is—

$$V = \frac{H+a}{a} V_0.$$

Where H = height above ground at which velocity is required.
 V = velocity at height H .
 V_0 = velocity at ground level.
 a = a constant, which may be taken as approximately equal to the height of the station above sea level.

This formula is believed to hold until the "gradient velocity," or velocity calculated from the pressure distribution, is reached; almost always lower than 3,000 ft.

Wind Force

551.511.5

Wind force is estimated by the Beaufort scale, which is given below. The following relations hold between the various constants :—

$$\begin{aligned} P &= .003V^2, \\ P &= .0105B^3, \\ V &= 1.87 \sqrt[3]{B^3}. \end{aligned}$$

Where P = pressure on a normal plane in pounds per square foot.
 V = velocity in miles per hour.
 B = the Beaufort number.

These are the formulæ adopted by the Meteorological Office.

THE BEAUFORT WIND SCALE AND EQUIVALENTS IN FORCE AND VELOCITY

Beaufort No.	General Description.	Characteristics.	Wind Force, on Normal Planet Standard Density		Limits of Velocities.			
			In Lbs. per Sq. Ft.	In Millibars (10 ⁹ Dynes per Cm. ²)	Statute Miles per Hour.	Nautical Miles per Hour.	Metres per Second.	Feet per Second.
					Less than 1 1-3	Less than 1 1-3	Less than 0.3 0.3-1.5	Less than 2 2-5
0	Calm	Smoke rises vertically.	0	0				
1	Light air	Direction of wind shown by smoke drift, but not by vanes.	.01	.01				
2	Slight breeze	Wind felt on face; leaves rustle; ordinary vanes moved by wind.	.08	.04	4.7	4.6	1.6-3.3	6-11
3	Gentle breeze	Leaves and small twigs in constant motion; wind extends light flag.	.28	.13	8-12	7-10	3.4-5.4	12-18
4	Moderate breeze	Raises dust and loose paper; moves small branches.	.67	.32	13-18	11-16	5.5-8.0	19-27
5	Fresh breeze	Small trees in leaf begin to sway; wavelets form on inland waters.	1.31	.62	19-24	17-21	8.1-10.7	28-36
6	Strong breeze	Large branches in motion; whistling heard in telegraph wires.	2.3	1.1	25-31	22-27	10.8-13.8	37-46
7	High wind	Whole trees in motion; inconvenience in walking against wind.	3.6	1.7	32-38	28-33	13.9-17.1	47-56
8	Gale	Breaks twigs of trees and generally impedes progress.	5.4	2.6	39-46	34-40	17.2-20.7	57-68
9	Strong gale	Slight structural damage occurs; chimney pots and slates removed.			47-54	41-47	20.8-24.4	69-80
10	Whole gale	Seldom experienced inland; trees uprooted, considerable structural damage.	10.5	5.0	55-63	48-55	24.5-28.4	81-93
11	Storm	Very rarely experienced; accompanied by widespread damage.	14.0	6.7	64-75	56-65	28.5-33.5	91-110
12	Hurricane	...	Above 17.0	Above 8.1	Above 75	Above 65	33.6 or above.	Above 110

THERMOMETER SCALES

551.52

THERMOMETER SCALES

	Centigrade, (Celsius) C. deg.	Fahrenheit, F. deg.	Réaumur, R. deg.	Absolute Scale, A. deg.
Boiling point of water at 760 mm. pressure of mercury	100	212	80	373
Freezing point of water at 760 mm. pressure of mercury	0	32	0	273
Absolute zero	-273	-461	-218.4	0
1 Centigrade degree = To convert C. degrees	1 ...	$\frac{9}{5}$ or 1.8 (C $\times$ 1.8) + 32	$\frac{4}{5}$ or 0.8 C. $\times$ 0.8	1 C. + 273
1 Fahrenheit degree = To convert F. degrees	$\frac{5}{9}$ or 0.5 0.5 (F. - 32)	1 ...	$\frac{4}{9}$ or 0.4 0.4 (F. - 32)	$\frac{5}{9}$ or 0.5 0.5 (F. - 32) + 273
1 Réaumur degree = To convert R. degrees	$\frac{4}{5}$ or 1.25 1.25 R.	$\frac{9}{4}$ or 2.25 2.25 R + 32	1 ...	$\frac{5}{4}$ or 1.25 1.25 R + 273
1 Absolute degree = To convert absolute degrees	1 A. - 273	$\frac{9}{5}$ or 1.8 1.8 (A. - 273) + 32	$\frac{4}{5}$ or 0.8 0.8 (A. - 273)	1 ...

NOTE.—In the case of conversions add or subtract algebraically when any temperatures are below zero.

CONVERSION OF THERMOMETER READINGS

DEGREES FAHRENHEIT AND CENTIGRADE

* Fahr.	*	* Cent.	* Fahr.	*	* Cent.	* Fahr.	*	* Cent.
32	0	-17.7	59	15	-9.4	230	110	43.3
33.8	1	-17.2	68	20	-6.6	248	120	48.8
35.6	2	-16.6	86	30	-1.1	266	130	54.4
37.4	3	-16.1	104	40	4.4	284	140	60.0
39.2	4	-15.5	122	50	10.0	302	150	65.5
41.0	5	-15.0	140	60	15.5	320	160	71.1
42.8	6	-14.4	158	70	21.1	338	170	76.6
44.6	7	-13.8	176	80	26.6	356	180	82.2
46.4	8	-13.3	194	90	32.2	374	190	87.7
48.2	9	-12.7	212	100	37.7	392	200	93.3
50	10	-12.2				413.6	212	100

* The figures in these columns refer to either side, e.g., 0 deg. C. = 32 deg. F., or 0 deg. F. = 17.7 deg. C.

DE-DA (Detachable Data) System
R. Borlase Matthews' Patents (provisionally protected) U.S. Patents applied for.

CONVERSIONS

551.54

CONVERSION OF BAROMETRIC HEIGHT IN INCHES OF MERCURY AT 32° F., LATITUDE 45°, TO ATMOSPHERIC PRESSURE IN MILLIBARS. (British and French Official Standards.)

(1,000 millibars are equivalent to the pressure of a column of mercury 750.076 mm. (29.5306 in.) high at 0° C. (273 deg. absolute) in latitude 45° = 1 atmosphere. 1 mb. is $\frac{1}{1000}$ th part of the atmospheric pressure.)

Conversions $\left\{ \begin{array}{l} 1 \text{ in.} = 25.4 \text{ mm.} = 33.9 \text{ mb.} \\ 0.0394 \text{ ,,} = 1 \text{ ,,} = 1.33 \text{ ,,} \\ 0.0295 \text{ ,,} = 0.75 \text{ ,,} = 1 \text{ ,,} \end{array} \right.$

Ins.	Milli- bars.	Ins.	Milli- bars.	Ins.	Milli- bars.	Ins.	Milli- bars.	Ins.	Milli- bars.
28.00	948.2	28.60	68.5	29.20	88.8	29.80	09.1	30.40	29.4
2	48.8	2	69.2	2	89.5	2	09.8	2	30.1
4	49.5	4	69.8	4	90.2	4	10.5	4	30.8
6	50.2	6	70.5	6	90.8	6	11.2	6	31.5
8	50.9	8	71.2	8	91.5	8	11.8	8	32.2
28.10	51.6	28.70	71.9	29.30	92.2	29.90	12.5	30.50	1032.8
2	52.2	2	72.6	2	92.9	2	13.2	2	33.5
4	52.9	4	73.2	4	93.5	4	13.9	4	34.2
6	53.6	6	73.9	6	94.2	6	14.5	6	34.9
8	54.3	8	74.6	8	94.9	8	15.2	8	35.5
28.20	54.9	28.80	75.3	29.40	95.6	30.00	1015.9	30.60	36.2
2	55.6	2	75.9	2	96.3	2	16.6	2	36.9
4	56.3	4	76.6	4	96.9	4	17.3	4	37.6
6	57.0	6	77.3	6	97.6	6	17.9	6	38.2
8	57.7	8	78.0	8	98.3	8	18.6	8	38.9
28.30	58.3	28.90	78.6	29.50	999.0	30.10	19.3	30.70	39.6
2	59.0	2	79.3	2	99.6	2	20.0	2	40.3
4	59.7	4	80.0	3	1000.0	4	20.6	4	41.0
6	60.3	6	80.7	4	1000.3	6	21.3	6	41.6
8	61.0	8	81.4	6	01.0	8	22.0	8	42.3
				8	01.7				
28.40	61.7	29.00	982.0	29.60	02.4	30.20	22.7	30.80	43.0
2	62.4	2	82.7	2	03.0	2	23.3	2	43.7
4	63.1	4	83.4	4	03.7	4	24.0	4	44.3
6	63.7	6	84.1	6	04.4	6	24.7	6	45.0
8	64.4	8	84.7	8	05.1	8	25.4	8	45.7
28.50	965.1	29.10	85.4	29.70	05.7	30.30	26.1	30.90	46.4
2	65.8	2	86.1	2	06.4	2	26.7	2	47.1
4	66.5	4	86.8	4	07.1	4	27.4	4	47.7
6	67.1	6	87.5	6	07.8	6	28.1	6	48.4
8	67.8	8	88.1	8	08.4	8	28.8	8	49.1

The whole range of variation within a year will only be between 940 mb. and 1,060 mb. (with a possible rare exception of, say, 925 mb.).

TABLE OF ALTITUDES
AT MEAN TEMPERATURE OF ATMOSPHERE OF 10° C. (50° F.)
(Airey)

Aneroid or Corrected Barometer.	Height in Feet.	Aneroid or Corrected Barometer.	Height in Feet.	Aneroid or Corrected Barometer.	Height in Feet.	Aneroid or Corrected Barometer.	Height in Feet.
In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.
31.00	0	30.10	800	29.23	1,600	28.38	2,400
30.94	50	30.04	850	29.17	1,650	28.33	2,450
30.88	100	29.99	900	29.12	1,700	28.28	2,500
30.83	150	29.93	950	29.07	1,750	28.23	2,550
30.77	200	29.88	1,000	29.01	1,800	28.18	2,600
30.71	250	29.82	1,050	28.96	1,850	28.12	2,650
30.66	300	29.77	1,100	28.91	1,900	28.07	2,700
30.60	350	29.71	1,150	28.86	1,950	28.02	2,750
30.54	400	29.66	1,200	28.80	2,000	27.97	2,800
30.49	450	29.61	1,250	28.75	2,050	27.92	2,850
30.43	500	29.55	1,300	28.70	2,100	27.87	2,900
30.38	550	29.50	1,350	28.64	2,150	27.82	2,950
30.32	600	29.44	1,400	28.59	2,200	27.76	3,000
30.26	650	29.39	1,450	28.54	2,250	27.71	3,050
30.21	700	29.34	1,500	28.49	2,300	27.66	3,100
30.15	750	29.28	1,550	28.43	2,350	27.61	3,150

TABLE OF ALTITUDES
AT MEAN TEMPERATURE OF ATMOSPHERE OF 10° C. (50° F.)—Continued
(Airey)

Aneroid or Corrected Barometer.		Height in Feet.	Aneroid or Corrected Barometer.		Height in Feet.	Aneroid or Corrected Barometer.		Height in Feet.	Aneroid or Corrected Barometer.		Height in Feet.
In.	Ft.		In.	Ft.		In.	Ft.		In.	Ft.	
27.56	3,200		26.47	4,100		25.80	5,000		24.96	5,900	
27.51	3,250		26.42	4,150		25.75	5,050		24.92	5,950	
27.46	3,300		26.37	4,200		25.71	5,100		24.87	6,000	
27.41	3,350		26.32	4,250		25.66	5,150		24.82	6,050	
27.36	3,400		26.27	4,300		25.61	5,200		24.78	6,100	
27.31	3,450		26.22	4,350		25.56	5,250		24.73	6,150	
27.26	3,500		26.17	4,400		25.52	5,300		24.69	6,200	
27.21	3,550		26.13	4,450		25.47	5,350		24.64	6,250	
27.16	3,600		26.08	4,500		25.42	5,400		24.60	6,300	
27.11	3,650		26.03	4,550		25.38	5,450		24.55	6,350	
27.06	3,700		26.18	4,600		25.33	5,500		24.51	6,400	
27.01	3,750		26.13	4,650		25.28	5,550		24.46	6,450	
26.96	3,800		26.09	4,700		25.24	5,600		24.42	6,500	
26.91	3,850		26.04	4,750		25.19	5,650		24.37	6,550	
26.86	3,900		25.99	4,800		25.15	5,700		24.33	6,600	
26.81	3,950		25.94	4,850		25.10	5,750		24.28	6,650	
26.76	4,000		25.89	4,900		25.05	5,800		24.24	6,700	
26.72	4,050		25.85	4,950		25.01	5,850		24.20	6,750	

TABLE OF ALTITUDES

551.54

TABLE OF ALTITUDES
AT MEAN TEMPERATURE OF ATMOSPHERE OF 10° C. (50° F.)—Continued
(Airey)

Aneroid or Corrected Barometer.	Height in Feet.	Aneroid or Corrected Barometer.	Height in Feet.	Aneroid or Corrected Barometer.	Height in Feet.	Aneroid or Corrected Barometer.	Height in Feet.
In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.
24.15	6,800	23.37	7,700	22.61	8,600	21.87	9,500
24.11	6,850	23.32	7,750	22.57	8,650	21.83	9,550
24.06	6,900	23.28	7,800	22.52	8,700	21.79	9,600
24.02	6,950	23.24	7,850	21.48	8,750	21.75	9,650
23.97	7,000	23.20	7,900	22.44	8,800	21.71	9,700
23.93	7,050	23.15	7,950	22.40	8,850	21.67	9,750
23.89	7,100	23.11	8,000	22.36	8,900	21.63	9,800
23.84	7,150	23.07	8,050	22.32	8,950	21.59	9,850
23.80	7,200	23.03	8,100	22.28	9,000	21.55	9,900
23.76	7,250	22.98	8,150	22.24	9,050	21.51	9,950
23.71	7,300	22.94	8,200	22.20	9,100	21.47	10,000
23.67	7,350	22.90	8,250	22.16	9,150	21.44	10,050
23.62	7,400	22.86	8,300	22.11	9,200	21.40	10,100
23.58	7,450	22.82	8,350	22.07	9,250	21.36	10,150
23.54	7,500	22.77	8,400	22.03	9,300	21.32	10,200
23.50	7,550	22.73	8,450	21.99	9,350	21.28	10,250
23.45	7,600	22.69	8,500	21.95	9,400	21.24	10,300
23.41	7,650	22.65	8,550	21.91	9,450	21.20	10,350

D.E.D.A. (Detachable Data) System
K. Borlase Matthews. Patents (personally protected). U.S. Patents applied for.

TABLE OF ALTITUDES

551.54

TABLE OF ALTITUDES
AT MEAN TEMPERATURE OF ATMOSPHERE OF 10° C. (50° F.).—Continued
(Airy)

Aneroid or Corrected Barometer.	Height in Feet.	Aneroid or Corrected Barometer.	Height in Feet.	Aneroid or Corrected Barometer.	Height in Feet.	Aneroid or Corrected Barometer.	Height in Feet.
In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.
21.16	10,400	20.74	10,950	20.36	11,450	19.99	11,950
21.12	10,450	20.70	11,000	20.32	11,500	19.95	12,000
21.08	10,500	20.66	11,050	20.29	11,550	19.91	13,000
21.05	10,550	20.63	11,100	20.25	11,600	18.88	14,000
21.01	10,600	20.59	11,150	20.21	11,650	17.88	15,000
20.97	10,650	20.55	11,200	20.18	11,700	17.235	16,000
20.93	10,700	20.51	11,250	20.14	11,750	16.615	17,000
20.89	10,750	20.47	11,300	20.10	11,800	16.016	18,000
20.85	10,800	20.44	11,350	20.07	11,850	15.439	19,000
20.82	10,850	20.40	11,400	20.03	11,900	14.883	20,000
20.78	10,900	...	...	...	...	...	...

A fall of 1 in. in the barometer indicates a rise of approximately 900 ft. in the elevation, so that the product of 900 and the difference between the aneroid readings at two altitudes will give the approximate difference of altitude in feet, should an altitude scale not be available.

For temperatures above or below 50° F., add together the thermometer readings at the two altitudes. If this sum is greater than 100° F., increase the height by 1-1000th part for every degree in excess of 100° F. If the sum is less, decrease in the same proportion. This method is, of course, only an approximation.

(Pressure at Ground Level 29.9 in.)

STANDARD ATMOSPHERE

551.54

TEMPERATURE CORRECTIONS TO ALTIMETER HEIGHTS

Altimeter Height.	Average True Height (Feet) for Ground Temperature.				
Ft.	-5° C.	+5° C.	+15° C.	+25° C.	+35° C.
5,000	4,670	4,840	5,010	5,180	5,350
10,000	9,200	9,530	9,870	10,200	10,530
15,000	13,610	14,090	14,580	15,069	15,540
20,000	17,890	18,520	19,150	19,770	20,390
25,000	22,060	22,830	23,590	24,340	25,100
30,000	26,120	27,010	27,900	28,780	29,660

On account of inversions of temperature near the ground, the true height can be estimated even more accurately by adding 7° C. to the temperature of 5,000 ft. above the ground.

It will be noted that the corrections required are considerable for heights over 5,000 ft. For bombing purposes, the height must be known accurately.

On account of lag, an altimeter generally reads too low on ascending, and too high on descending.

STANDARD ATMOSPHERE

Altitude. Feet.	Pressure in In. of Mercury.	Deg. Cent.	Density.	Altitude. Feet.	Pressure in In. of Mercury.	Deg. Cent.	Density.
...	29.92	15.0	1.000	16,000	16.30	-12.8	0.603
1,000	28.856	12.8	0.972	17,000	15.66	-14.1	0.582
2,000	27.826	10.7	0.944	18,000	15.05	-15.3	0.566
3,000	26.82	8.7	0.917	19,000	14.45	-16.6	0.542
4,000	25.846	6.7	0.889	20,000	13.88	-17.8	0.523
5,000	24.90	4.7	0.863	21,000	13.36	-18.8	0.506
6,000	23.99	3.6	0.835	22,000	12.84	-19.6	0.487
7,000	23.10	1.2	0.814	23,000	12.35	-21.0	0.472
8,000	22.24	-0.5	0.786	24,000	11.79	-22.3	0.452
9,000	21.41	-2.1	0.761	25,000	11.29	-23.0	0.434
10,000	20.60	-3.8	0.737	26,000	10.90	-23.4	0.421
11,000	19.83	-5.5	0.722	27,000	10.45	-24.2	0.408
12,000	19.06	-7.0	0.690	28,000	10.04	-25.3	0.390
13,000	18.33	-8.6	0.667	29,000	9.64	-26.3	0.376
14,000	17.63	-10.1	0.646	30,000	9.27	-27.3	0.363
15,000	16.95	-11.5	0.624	...	...	...	...

CONVERSION OF BAROMETRIC READINGS— MILLIMETRES TO INCHES

1 mm. = 0.03937 in. (approx. $\frac{1}{25}$) [log. 2.595 1654]

1 in. = 25.40005 mm. (approx. $\frac{1}{4} \times 100$) [log. 1.404 8346]

Milli- metres.	Inches.	Milli- metres.	Inches.	Milli- metres.	Inches.	Milli- metres.	Inches.
800	31.50	754	29.69	706	27.80	535	21.06
798	31.42	753	29.65	704	27.72	530	20.87
796	31.34	752	29.61	702	27.64	525	20.67
794	31.26	751	29.57	700	27.56	520	20.47
792	31.19	750	29.53	695	27.36	515	20.28
790	31.11	749	29.49	690	27.17	510	20.08
788	31.03	748	29.45	685	26.97	505	19.88
786	30.95	747	29.41	680	26.77	500	19.69
784	30.87	746	20.37	675	26.58	490	19.29
782	30.79	745	29.34	670	26.38	480	18.90
780	30.71	744	29.30	665	26.18	470	18.50
779	30.67	743	29.26	660	25.99	460	18.11
778	30.64	742	29.22	655	25.79	450	17.72
777	30.60	741	29.18	650	25.59	440	17.32
776	30.56	740	29.14	645	25.40	430	16.93
775	30.52	739	29.10	640	25.20	420	16.53
774	30.48	738	29.06	635	25.00	410	16.14
773	30.44	737	29.02	630	24.80	400	15.75
772	30.40	736	28.98	625	24.61	390	15.36
771	30.36	735	28.94	620	24.41	380	14.96
770	30.32	734	28.90	615	24.21	370	14.57
769	30.28	733	28.86	610	24.02	360	14.17
768	30.24	732	28.82	605	23.82	350	13.78
767	30.20	731	28.78	600	23.62	340	13.39
766	30.16	730	28.74	595	23.43	330	12.99
765	30.12	728	28.66	590	23.23	320	12.60
764	30.08	726	28.58	585	23.03	310	12.21
763	30.04	724	28.51	580	22.84	300	11.81
762	30.00	722	28.43	575	22.64	280	11.02
761	29.96	720	28.35	570	22.44	260	10.24
760	29.92	718	28.27	565	22.25	240	9.45
759	29.88	716	28.19	560	22.05	220	8.66
758	29.85	714	28.11	555	21.85	200	7.87
757	29.81	712	28.04	550	21.65	150	5.91
756	29.77	710	27.96	545	21.46	100	3.94
755	29.73	708	27.88	540	21.26	50	1.97

D.E.D.A. (Detachable Data) System
R. Horlase Matheson Patents (provisionally protected) U.S. Patents applied for.

FOG

A fog is a cloud lying at the earth's surface.

Land fog is most prevalent in the day-time during autumn or winter; it also often occurs in the early mornings of summer. It is generally due to cold air passing over relatively warm moist ground.

Fog is also caused by warm air saturated with water vapour passing over a cold surface, which chills and condenses it. Other forms are radiation fog and cliff fog. Sea fogs occur chiefly in the spring and summer when the air is warming rapidly, and are infrequent in winter. Anticyclonic weather with light airs is very favourable for land fog, and the conclusion of a period of anticyclonic weather is nearly always accompanied by a fog.

Fog may also be anticipated, when the wind changes from a northerly or easterly to a southerly point.

Fogs may last over twenty-four hours, and be renewed day after day. If large drops of water form in a fog, it is a sure sign that the fog will disappear very shortly.

Major G. I. Taylor, in a paper read before the Royal Aeronautical Society, described a Fog Prediction Chart that he had devised; a reproduction of this diagram is given herewith. It may be conveniently used for forecasting whether fog is likely to appear on an aerodrome or not during the night.

To employ the chart, a point is ascertained representing the state of the air at a given time, preferably 8 p.m. This is arrived at by setting out the air temperature, and the difference of the wet and dry bulb thermometers, and marking the point where the two lines cross. If the wind is less than 5.5 m.p.h., and if the sky is not completely covered with clouds, then a fog is probable as long as the point lies below the dotted 8 p.m. line. If it lies above, however, the chances are that no fog will occur. A difference of

SCALE OF FOG INTENSITY

Scale.	Name.	On Sea.	On River.
0	No fog or mist	Horizon clear.	
1	Light fog or mist	Horizon invisible, but lights and landmarks generally visible at working distances.	Objects indistinct but navigation unimpeded.
2	Moderate fog	Lights, passing vessels, and landmarks generally indistinct under a mile. Fog signals are sounded.	Navigation impeded, additional caution required.
3	Thick fog	Ships' lights and vessels invisible at $\frac{1}{4}$ mile or less.	Navigation suspended.

The chart is a grid-based plot with the following features:

- Vertical Axis (Left):** Labeled "DIFFERENCE BETWEEN WET & DRY BULBS" with values from 0 to 12 in increments of 2.
- Horizontal Axis (Bottom):** Labeled "AIR TEMPERATURE" with values from 30° to 80° in increments of 10°.
- Curves:** A series of solid curves sloping downwards from left to right, labeled with values 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, and 26. These represent the difference between wet and dry bulb temperatures.
- Dashed Line:** A dashed line sloping downwards from left to right, labeled "THIS LINE FOG NOT EXPECTED FOR 2 HOURS".
- Annotations:**
 - "ASSUMPTION: 1.1°" near the bottom left.
 - "THIS LINE FOG NOT EXPECTED FOR 2 HOURS" written twice along the dashed line.
 - "THIS LINE FOG NOT EXPECTED FOR 2 HOURS" written vertically along the right side of the chart.

Fog Prediction Chart.

*"Lib-LA (Detachable Data) System
R. Borlase Martinez's Patents (provisionally protected). U.S. Patents applied for.*

Clouds

Certain types of cloud and the direction from which they are moving indicate certain states of weather.

In general, soft looking clouds accompany fine weather, and those with clear and well-defined edges presage wind. Ragged clouds and light scud are the forerunners of strong wind and rain.

It is characteristic of clouds that each type is normally found within definite heights. A knowledge of cloud forms therefore provides an indication as to their heights above the surface of the earth.

When the engine of an aeroplane stops, the machine must come down somewhere inside a circle whose radius is about equal to five times its height above ground level. Clouds below 5,000 ft. therefore tend to make flying dangerous, for when engine failure occurs at a height below 5,000 ft., the landing area is obviously restricted.

Cirrus and cirro-stratus clouds, whose altitude above sea level averages about five miles, consist of minute crystals of ice; all other clouds are composed of fine particles of water.

Neither crystals nor drops actually float in the air. They are constantly falling with respect to the air around them, though, as the air itself often has an upward movement, the cloud particles are not always falling with reference to the earth. This fact is of considerable interest to aviators, and those interested in soaring flight.

HEIGHT AND VELOCITY OF CLOUDS

Position.	Name.	Average Height.	Velocity in Metres per Second.
		Metres.	•
Highest clouds - {	Cirrus	7,000-11,000	30-40
	Cirro-stratus	7,000-9,000	30
	Cirro-cumulus	7,500	15-35
Moderately high clouds - {	Alto-cumulus	3,000-6,000	15
	Alto-stratus	4,000-6,000	20
	Cumulo-stratus	1,500-2,500	10
Low clouds - {	Nimbus	500-1,500	...
	Cumulus	1,500	10
Clouds in ascending columns of air {	Cumulus-nimbus	1,500-1,400	15
	(thunder clouds)		
Ground fog - {	Stratus	500	7

I.—CLOUD SHEETS

Upper (Cirrus) cloud layer about 30,000 ft. Clouds composed of ice crystals. With these are sometimes seen halos, or rings, at some distance from the sun and moon.

Cirrus.—Mares' tails; flexuous fibres; wisps or lines of pure white clouds with no shadows.

Cirro-cumulus.—Small speckles and flocks of white clouds; fine ripple clouds; mackerel sky; a forerunner of storms.

Cirro-stratus.—A thin sheet of tangled web structure, sometimes covering the whole sky; watery sun or moon.

Cirro-nebula.—Similar to the last, but a veil of cloud with no visible structure.

Middle (Alto) cloud layer, 10,000 ft. to 25,000 ft. Clouds composed of minute drops of water. Coloured rings sometimes seen quite close to sun and moon, but never halos.

Alto-cumulus.—Somewhat similar to cirro-cumulus, but the cloud masses are larger and show some shadow.

Alto-cumulus Castellatus.—Turret cloud; alto-cumulus with upper margins of the cloud masses developed upwards into miniature cumulus, with hard upper edges. (Sign of thunder.)

Alto-stratus.—Very like cirro-stratus and cirro-nebula, but a thicker and darker cloud.

Lower cloud layer.
Below 7,000 ft.

Strato-cumulus.—Cloud masses with some vertical structure; rolls or waves sometimes covering the whole sky.

Stratus.—A uniform layer of cloud resembling fog, but not resting on the ground.

Nimbus.—Shapeless dense black cloud without structure from which falls continuous rain or snow.

Scud (Fracto-nimbus).—Small shapeless clouds with ragged edges; sometimes seen without other cloud, especially in hilly country; but more commonly seen below other clouds, such as cumulus and nimbus.

DE-D.A (Detachable Data) System
R. Boyle Matthews' Patents (provisionally protected). U.S. Patents applied for

WEATHER FORECASTS

551-591

II.—HEAP CLOUDS

The height of the heap clouds is very variable. Mean height of base, about 4,500 ft.; the height of the top varies from about 6,000 to 25,000 ft.

Cumulus.—Woolpack clouds; clouds with flat base and considerable vertical height. Cauliflower-shaped top; fair weather clouds when small, showery when large and piled up; when very large and ragged at the top, cause local thunderstorms.

Fracto-cumulus.—Small cumulus with ragged tops.

Cumulo-nimbus.—Anvil cloud, thunder cloud, or shower cloud. Towering cumulus with the top brushed out in soft wisps or larger masses of fibrous cloud which are called false cirrus, and the base is a rain cloud.

WEATHER FORECASTS

551-591

No meteorologist, in the modern sense, attempts to forecast the weather without reference to a map prepared either by himself or by some one with whom he is in direct communication, from observations transmitted by telegraph for the purpose. No amount of weather-wisdom or weather-lore or experience is a substitute for the map. The more expert and accomplished the meteorologist the more certain he is that all he can do without the materials for constructing a map, though he may have a barometer and other instruments at hand, is to make a guess at what the map is like, and think out from that what the weather changes are likely to be (Sir Napier Shaw).

When proper weather maps are unobtainable weather may be very fairly foretold under certain conditions by the empirical observer, but he must be one who, like the far-famed "Shepherd of Banbury," from long practice recognises the slightest change in the look of the sky or the feel of the atmosphere. His guides will be the colour of the sky, the formation of the clouds, and the temperature and indications of the pressure of the atmosphere.

Many weather maxims have been handed down to the present generation. These rhymes have some truth in them, for they are the crude but honest expressions of men who had had life-long experience of the weather and its variableness. These worthy men of old, with all their knowledge of the weather, often based their maxims purely on averages, which have been proved to be

It may be well to quote here a few of the maxims which have been proved to have a sound meteorological basis:—

**"When the wind shifts against the sun,
Trust it not, for back it will run."**

To-day one can gain more accurate information than such weather wiseacres as the reputed "Shepherd of Banbury," by referring to barometers and weather charts which record with remarkable exactitude. A weather forecast's period of anticipation, however,

even under these most scientific conditions, does not exceed thirty-six hours, except in the case of set anticyclonic conditions, known to be travelling in a certain direction. It will indicate the direction and force of the surface-wind, and any likely change that may occur within the stated twenty-four hours. It will also register the form of the clouds and prognosticate a likely fall of rain, hail, snow, or sleet, or a change in the temperature. Again, it will forecast night frost, fog, or thunder. All this knowledge is gained through the study of distributed pressure, which is recorded by the barometer at a number of widely placed stations. For the aviator's benefit a record is given of the wind at 1,500 ft. Records of changes at higher altitudes are considered unnecessary, as they can only be very gradual.

Barometric prognostication has been proved almost invariably reliable. It acts in the following way: supposing the wind changes suddenly round to the south, this will produce a sudden fall in the barometer; from that, advancing depression is deduced, which will of necessity be followed by rain in due course.

The great disadvantage that the Germans suffered from in their air attacks was their lack of knowledge of weather out in the Atlantic.

On the average in England, the wind is strongest between 11 A.M. and 4 P.M. during March and April, and lightest between midnight and dawn from June to September. As a rule, September, followed by July, are the best months for light winds, and March is the month of the heaviest winds.

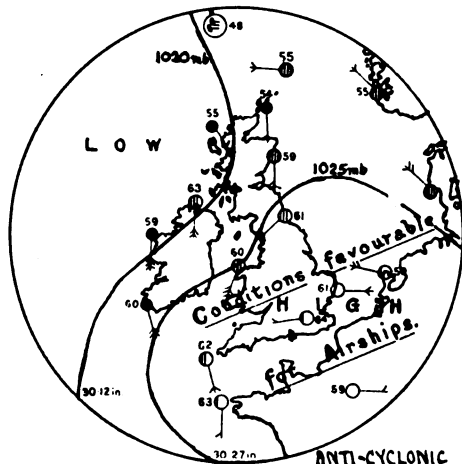
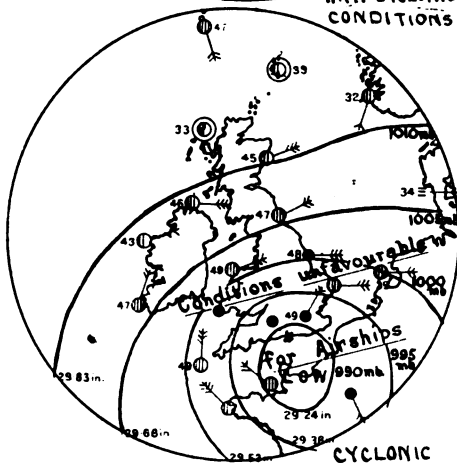
General Indications

Valuable information is contained in the daily weather charts published by the Meteorological Office and from the abstracts in various newspapers. The lines of equal barometric pressure, or **isobars**, show the general distribution of atmospheric pressure, from which the probable winds can be foretold. There are two main types of distribution of the isobars, as shown in the illustrations, and with these all other types are more or less intimately associated.

A **cyclone**, or depression, is a definite area of low pressure; usually characterised by strong winds, rough, unsettled weather, and a temperature low in summer and high in winter. The winds blow spirally towards the low-pressure area in an anti-clockwise direction. The motion, as a rule, is from west to east.

An **anticyclone** is a definite area of high pressure: characterised by light airs and calms, dry, hazy, or foggy weather, and a temperature high in summer and low in winter. The winds blow outwards from the high-pressure area in a clockwise direction. It has no general direction of motion.

The centre of a cyclone is a general area of ascending air currents, and that of an anticyclone of descending air currents.

ANTI-CYCLONIC
CONDITIONSCYCLONIC
CONDITIONS.

ISOBARS are drawn for intervals of five millibars.
WIND.—Direction is shown by arrows flying with the wind.
 Force on the scale 0-12, is indicated by the number of feathers.
 C.F.M.

WEATHER.—Shown by the following symbols:—
 ○ clear sky ☁ sky & clouded.
 ☁ sky & clouded. ☁☁ sky & clouded.
 ☁☁ overcast sky ☁☁ rain falling
 * snow. * fog
 ≡ hail. T thunder.
 T thunderstorm.

TEMPERATURE.—Given in degrees Fahrenheit.

INTERPRETATION OF BAROMETER READINGS 551-591

The intervals between the isobars usually correspond to differences in pressure of one-tenth of an inch. A cyclone with crowded isobars always has strong winds; when the isobars are widely spaced the winds are gentle.

Cyclones are usually preceded by rising temperature, and accompanied by cloudiness, and rain or snow.

Anticyclones are usually preceded by falling temperature, and attended by fair weather.

Forty-eight hours is about the present limit of the possibilities of forecasting the weather with any degree of accuracy. Forecasts for a week in advance are made by Meteorological Offices, with the aid of reports from a chain of stations extending round the world, but these are bound at present to be in very general terms.

When anticyclonic conditions are established, the forecasting of favourable weather for air raids is quite a simple matter. Similarly it is quite easy to recognise a day or two in advance the periods of unfavourable weather, by a study of weather maps. Forecasting in the case of risky weather (cyclonic conditions) is, however, an entirely different matter requiring expert skill.

Local Indications

Local indications which assist in a forecast are the behaviour of the barometer and thermometer, and the aspect of the sky and clouds.

INTERPRETATION OF BAROMETER READINGS

Rise (general characteristics) - N.E.ly (N.W.-N.-E.) dry or less wind (except wet from N.E.l.).

Rate of Rise:—

Uniform (an ascending straight line on a recording barometer chart)

Weather improves.

Increasing (a concave line on a recording barometer chart)

Weather improves more rapidly.

Decreasing (a convex line on a recording barometer chart)

Weather improves less rapidly.

The quicker the rise, the steeper the isobars, and therefore - - -

The stronger the wind.

Rapid rise - - -

Unsettled weather, liability to sudden changes.

Gradual rise - - -

With a dry atmosphere, fair weather. After southerly winds, improving tendency with wind from W. or N.W.

Rise above normal (over 30 in. or 1,016 mb.)	Fine weather and moderate winds (except from E. and N. occasionally).
Steady rise from normal (over 30 in. or 1,016 mb.). Thermometer falling. Dry atmosphere	N.W., N., or N.E. wind, or less wind, less rain (or snow).
Rise from below normal (29½ in. or 999 mb.)	Less wind or a change in its direction towards N.—or less wet.
Rise from low (say 29 in. or 982 mb.). First rise	Strong wind or heavy squalls from N.W., N., or N.E.
Continued rise. (Falling thermometer)	Improving weather.
Continued quick rise. (Thermometer rising)	Wind will back (shift against the sun's course), and S. or S.W. wind will follow.
Rise from very low (below 29 in. or 982 mb.)	Heavy N. gale.
Steadiness (with dry atmosphere)	Fine weather.
Alternate Rising and Falling	Unsettled and threatening weather.
Fall (general characteristics)	For S.W.ly (S.E.-S.-W.). Wet or more wind (except wet from N.E.).
Rate of Fall:—	
Uniform (a descending straight line on a recording barometer chart)	Wind and weather get worse
Increasing (a convex line on a recording barometer chart)	Wind and weather get much worse.
Decreasing (a concave line on a recording barometer chart)	Wind and weather get worse slowly.
The quicker the fall, the steeper the isobars, and therefore - - -	The stronger the wind.
Rapid fall - - -	Stormy weather and rain. If with westerly wind, storms from southward.
Considerable fall - -	High wind, rain, or snow; wind from N. if thermometer is low, from S. if it is high.
Steady fall from normal (30 in. or 1,016 mb.). Thermometer rising. Increasing dampness	Rain and wind from S.E., S., or S.W.

ASPECT OF THE CLOUDS

551.591

Steady fall from normal, thermometer falling	Snow.
Fall after northerly winds	Bad tendency, wind probably shifting to S.
Fall after northerly winds, with high or increasing temperature	Winds from S. or S.W., possible rain.
Fall with a north wind	Strong wind and rain.
Sudden fall with westerly wind	Violent storm from N.W. or N. or N.E.
Fall with a gale set in from E. or S.E.	Gale continues, and the wind veers by the S. until it is near a marked change, when a lull <i>may</i> occur; after which the gale will be renewed, wind veer to N.W., N., or N.E.; barometer will then rise, and thermometer fall.

ASPECT OF THE SKY AND CLOUDS

Sky at Sunset:—

Rosy	-	-	-	-	Fine weather.
Red	-	-	-	-	Fair weather.
Dark or Indian red	-	-	-	-	Rain.
Pale yellow	-	-	-	-	Rain.
Unusual clearness of distant objects (due to refraction) and unusual audibility	-	-	-	-	Rain or wind.
Sickly greenish hue	-	-	-	-	Rain and wind.
Orange or copper coloured	-	-	-	-	Rain and wind.
Tawny or coppery clouds	-	-	-	-	Wind.
Bright yellow	-	-	-	-	Wind.
A great deal of refraction	-	-	-	-	Easterly wind.

Sky at Sunrise:—

Low dawn (first indications on the horizon)	-	-	-	-	Fine weather.
Grey	-	-	-	-	Fair weather.
Opal tinted	-	-	-	-	Rain.
Red	-	-	-	-	Rain or wind.
Dark red	-	-	-	-	Heavy rain or strong wind.
High dawn (first indications above a bank of clouds)	-	-	-	-	Wind.

ASPECT OF THE CLOUDS

Certain types of cloud and the direction from which they are moving indicate certain states of weather. In general, soft looking

clouds accompany fine weather, and those with clear and well-defined edges presage wind. Ragged clouds and light scud are the forerunners of strong wind and rain. The softer that clouds appear, the less wind, but possibly more rain may be anticipated.

Light bright blue sky	-	Fine weather.
Light, delicate quiet tints or colours with soft in- definite clouds		Fine weather, or moderate winds.
Formation of dew	-	Fine weather.
Misty clouds formed and hanging on heights, but rising and dispersing		Fair weather.
Light curls, streaks, wisps, or mottled patches of dis- tant cloud appearing after fine clear weather, de- veloping into watery cloudy vapour		Rain.
Small inky-looking clouds	-	Rain.
Gaudy or unusual hues with hard definitely outlined clouds		Rain and probable strong wind.
Light scud clouds driving across heavy masses		Rain and wind.
Increased twinkling of stars, greater apparent size of halos, etc.		Probable wind with or without rain.
Light scud clouds over big ragged clouds		Rain and strong wind.
Hard-edged, oily looking clouds		Wind.
Dark, gloomy blue sky	-	Wind.
Light scud clouds alone	-	Wind of strength in proportion to motion.
Very hard, greasy, rolled, tufted, and ragged clouds		Strong wind.
Light curls, streaks, wisps, or mottled patches of dis- tant cloud, appearing after fine clear weather, developing into oily, cloudy vapour		Wind.
Misty clouds forming or hanging on heights, and then remaining, increas- ing, or descending		Rain and wind

DE-DA (Detachable Data) System
R. Berlese Mathews' Patents (provisionally protected). U.S. Patents applied for.

In conclusion, then, what are the atmospheric conditions necessary for safe flight, and what are those to be avoided? Anti-cyclonic conditions are undoubtedly the most favourable. An anti-cyclonic period may usually be depended upon when the wind is travelling from a north to a north-easterly direction, when the barometer is rising, and when the thermometer is falling. Pressures above 1,020 mb. (30.1 in.) are generally to be found in anticyclones, and under such conditions an aeroplane may rise 2,000 ft. higher than on an ordinary day. When well marked, anti-cyclonic weather may last from two to ten days. Beginners should also take advantage of the short lulls which are present as a rule in the intervals following, and often just prior to, dawn and sunset.

Cyclonic conditions, on the other hand, should naturally be avoided for safe flight. When the wind is veering from east to north-east, "bumps" are much more prevalent. South winds bring rain and mists. It must not be overlooked that settled periods of calm weather usually cause a fog or haze to collect low down, which would prevent an aviator 5,000 ft. up from observing objects, and would thus make landing dangerous.

612.275.2

PHYSIOLOGICAL EFFECTS OF FLYING

The chief effects noticed are: firstly, the "air sickness" due to the rolling and pitching of the aeroplane when flying in a wind. This is merely a form of sea sickness, and springs from the same causes. Secondly, there are various symptoms which follow on very high flights, and are essentially the same as the "mountain sickness" experienced in high altitudes in such places as the Andes. These are chiefly due to deficiency of oxygen, owing to the rarefied condition of the atmosphere in its upper levels, and can be remedied by occasional breaths of oxygen from an oxygen bottle.

When climbing, apathy, sleepiness, or general fatigue is often felt, due to the rapid fall of atmospheric pressure. As higher altitudes are reached, there are sometimes pains and ringing in the ears, owing to the congestion of the auditory organs. Relief for those who suffer in this way, is obtained by recourse to the method of Valsalva in ascending, and to the application of Toynbee's method in descending.

According to Dr G. von Liebig, the following symptoms are felt at great heights: (1) Palpitation of the heart, accompanied by an acceleration of its action and throbbing of the arteries; (2) Shallow breathing, and consequent shortness of breath; (3) Flickering before the eyes; (4) Faintness; (5) Coldness of the extremities; (6) Difficulty in eating or in drinking strong stimulants.

At still greater altitudes the pressure in the veins and capillaries is so increased as to cause exudations of blood from the mucous membranes of the mouth, nose, and eyes; the brain becomes affected because of the deficiency of oxygen in the arterial blood, and causes

dullness and dejection, loss of the various senses, and eventually unconsciousness; and there is the danger of frostbite because of the extreme cold.

Serious symptoms are not evident except at heights to which it would rarely be necessary or even possible for an aeroplane to reach. Further, a man who ascends almost daily to considerable heights and keeps himself in good physical form, finds no noticeable ill effects other than due to the cold. The latter difficulty is now mitigated to a large extent by electrically heated suits of clothing.

Precautions which should be practised are the taking of nourishment during a high flight in small but frequent quantities, also occasional whiffs of oxygen; and on returning, to descend slowly, since the auditory organs, the lungs, and the circulatory apparatus have to adjust themselves to a different air pressure, and are exposed to dangerous fatigues during high flights. More than one fatal accident has in all probability been caused by a too rapid descent. Further information on this subject will be found in books on practical flying. (Refer to Bibliography section of this book.)

*DE-DA (Detachable Data) System
R. Rorase Matthew's Patents (provisionally protected) U.S. Patents applied for.*

AIRCRAFT ELECTRICAL EQUIPMENT

Voltage and Distribution System.—The most usual electric supply potential is 12 volts. However, owing to the existence of a certain amount of 6-volt apparatus, it is usual to employ a 3-wire direct current system of distribution with 12 volts between the outers, and 6 volts between the middle and the outers. An accumulator battery of 6 two-volt cells is usually connected in parallel with the generator, and acts as a balancer on the 3-wire system (being charged at the same time). In this system, the accumulators and batteries are provided with centre tappings for connection to the middle wire of the distribution system.

A separate and similar accumulator battery is provided where the aircraft is equipped with wireless telegraphic apparatus, change-over switches being provided to permit of one battery being charged while the other is employed with the wireless equipment. The accumulator usually installed has a rated capacity of either 8, 15, or 30 ampere-hours (10 hour rating), furnishing 3·6, 6·8, or 14 amperes respectively for one hour before the final voltage falls to 10·8 volts on load.

Standard Aircraft Dynamos

Kw.	Watts.	Volts.	Amperes.	Normal r.p.m.
1/4	250	12	20	3,500
1/2	500	12	40	3,500

The smaller dynamo is a compound wound machine of the self-controlled voltage three-brush type (usually of Leitner or Lucas design). The larger machine is generally shunt wound, and is usually provided with a Tirrill type voltage regulator for the sake of the improved efficiency obtainable as compared with self-control systems.

Electrical Apparatus

Power.—Electric motor engine starter.

Illumination.—(1) Navigation lights. (2) Recognition lights. (3) Night landing lights. (4) Steering indicator. (5) Instrument lights.

Heating.—(1) Clothing. (2) Gun heaters. (3) Radiator water heaters.

Signals.—(1) Electric horns. (2) Aldis daylight signalling light.

Ignition.—Coil ignition.

Wireless Apparatus.—(1) Receiving and transmitting valves. (2) Spark transmission.

With the exception of the ignition and wireless apparatus (which is often 6-volt) most of the above apparatus is now standardised for a 12-volt circuit.

COLOUR SYSTEM FOR AIRCRAFT ELECTRIC WIRING

Colour.	Polarity.	Service Cables and Cleats.	Cores.			
			No.	General.	Wireless Set.	Telephone.
Red	Positive or +	Wireless.	1	Main positive.	Low potential	Head receiver.
Green	Mid-battery terminal.	Telephone.	2	Neutral or mid-battery.	Positive	...
Yellow	Generator series positive terminal.	Heating, lighting, etc.	3	...	Low potential	...
White	Negative or -.	Ignition.	4	...	Common or neutral	...
Blue	Negative or earthed.	...	5	...	High potential	...
Black or Dark blue	Negative or earthed.	...	6	...	Positive and oscillating circuits	...
Drab	...	...	7	...	Low potential negative	Microphone.
					...	Common leads.

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DE-DA (Detachable Data) System
R. Barker Matthews' Patents (provisionally protected) U.S. Patents applied for.

AIRCRAFT GENERATOR AIRSCREWS

621.3

Air screws.—Electric generators for aircraft work are usually driven by air screws, for, as a rule, it is not always easy to make provision for driving these generators by the engine; in fact, the current is often required from the generator when the engine is switched off for diving, etc. Various attempts have been made to design an air screw that will rotate at practically constant speed whatever may be the velocity of the air impinging upon it. Theoretically it has been shown that such a design is impossible, hence the air screw has to be selected which is most suitable for the average speed of the type of aeroplane to which it is fitted. Windings of the electric generator are then arranged to give, as nearly as possible, a standard potential in varying speeds, or else some form of Tirrill voltage regulator is used in conjunction with the generator.

The air screw speed will vary according to (a) the variation of the air velocity (due to the speed of the aeroplane), and (b) variation of atmospheric density (due to the altitude of the aeroplane), and (c) variation of electrical load.

AIRCRAFT GENERATOR AIRSCREWS

Velocity of Air.		No. of Blades.	Diameter.
250-Watt Generator.	500-Watt Generator.		
m.p.h.	m.p.h.		In.
115-140	140-150	2	18
90-115	115-140	2	18
70-90	90-115	2	18
55-70	60-70	4	21
45-55	50-60	2	24

The generators are attached to the aeroplane either (a) by means of tripod mounting attached to the side of the fuselage or (b) by clamping to one of the struts. The electric generators are made in cylindrical streamlined form without feet, and are held by means of metal straps. When it is feasible the generator and its air screw should be so fitted on the aeroplane as to come in the slip stream of the main air screw, the plane of rotation of the generator air screw being parallel to the plane of rotation of the main air screw. The boss of the air screw should preferably be in such a position that it is about three-fourths of the radius of the main air screw away from the axis of that main air screw.

Pole Finding.—In cases where the terminals on the accumulator or the cables therefrom are not clearly marked or coloured, it

is often necessary to determine their polarity. This may be done by one of the following methods:—(a) *Compass Method*.—Place a small compass above or below a cable, and temporarily connect the latter to a heater or other current-consuming device. Place the right hand, as it were, in the wire, with the palm facing the compass, the thumb pointing in the direction in which the north pole of the compass needle is deflected, then the fingers will be pointing in the direction that the current is passing through the wire. (b) *Pole Finding Paper*.—Damp a piece of this paper and bring the two ends of the cable from the accumulator on to this paper placing them about $\frac{1}{4}$ in. or so apart: the negative lead will leave a red mark. (c) *Blue Print Paper*.—This is used similarly to the pole finding paper, but in this case the positive lead leaves a white mark. (d) *Gassing*.—If the ends of the two wires are dipped in acidulated, or salt, water comparatively close together, bubbles of gas will be given off—the greater quantity will come from the negative lead. (e) *Lead Strips*.—If the ends of the leads are connected each to a small lead strip, and dipped in dilute sulphuric acid the strip connected to the negative lead will turn brown.

Navigation Lights.—These consist of port, starboard, and tail lights with bull's eye lenses. In each case the electric lamp is placed slightly out of focus with regard to the lens, in order to give a wide angle of divergence ahead or astern.

Morse Signal Lights.—Either a single light at the bottom of the fuselage or two lights connected together, one in each main plane, are employed for Morse signalling. Also a similar light is fitted on the top centre main plane pointing vertically upwards, and controlled by a separate tumbler switch. The reflectors of these lamps are of such curvature as to give a beam of light with a divergence of 90° , so that the light can be seen by an observer where the angle of elevation to the aeroplane is 45° . The fuselage light is usually provided with three interchangeable glasses, white, red, and green.

Aldis Daylight Signalling Light.—This consists of an overrun focussing type of metal filament lamp of about 50 c.p. This lamp is placed in front of a 4-in. magnifying mirror, which is pivoted so as to be capable of being rocked on a horizontal axis so as to move the beam through an angle of 8° .

Holt Flares.—These flares are employed for landing at night. They consist of a magnesium composition ignited electrically. The candle-power in the vertical direction is approximately 1,000, thus a very much more brilliant light is obtainable than is the case with ordinary electric landing lights. One of these flares is usually mounted near the extremity of the main planes. On large aeroplanes this equipment is duplicated.

D.E.D.A. (Detachable Data) System
R. Barlow Matthews' Patents (provisionally protected). U.S. Patents applied for.

ELECTRICALLY HEATED CLOTHING

Waistcoat.—This garment serves also as a distributor of the electric current to the gloves and boot inner soles. The heat is distributed over the whole of the body surface of the garment by means of fine insulated resistance wire. The current consumption is 2.5 amperes at 12 volts (25 watts). **Gloves.**—The current taken by each glove is 1 ampere at 12 volts (12 watts); the heat is applied to the back of the hand, fingers, and thumb. The current is taken to the body clothing by means of flexible connections terminating in a two-pin plug, which inserts into a socket on the sleeve of the waistcoat. **Boot Inner Soles.**—Current taken by each sole is 0.75 ampere at 12 volts (9 watts). Current is taken to each sole by means of flexible connections of about 4 ft. in length, which terminate in two-pin plugs for insertion in a special socket on the waistcoat.

A special switch box is provided on the right-hand side of the cockpit, to enable the wearer to switch on and off independently, as required, the heat on the body, hands, and feet respectively.

Gun Heaters.—The purpose of these heaters is to keep the breech mechanism sufficiently warm to prevent the lubricant becoming so viscous as to impede the proper working of the gun. Two heaters are employed for the Vickers gun, each with a current consumption of 2.08 amperes at 12 volts (25 watts). For the Lewis gun the current consumption is 3 amperes at 12 volts (36 watts).

An additional heater consuming 2.5 amperes at 12 volts (30 watts) is also employed for warming the drum of the Lewis gun, as it has been found by experiment that the ammunition detonates best at a temperature of about 70° Fahrenheit (21° centigrade).

SIGNAL INDICATORS

Aircraft Telegraph.—This is merely an adjunct to the telephone and speaking tube for the purpose of intercommunication between the crew of an aircraft. It consists of a series of electrically illuminated signal indicators and transmitters intended for definite orders such as port, starboard, steady, etc.

FIXING OF CABLES

Electric Cables.—When wiring up aircraft it is important that particular attention should be paid in fixing the cables so as not to damage such parts of the constructional work as hollow or built up spars, struts, longerons, etc. The cables should be secured by electricians' black adhesive tape when it would not be wise to employ cleats.

LOW TENSION FLEXIBLE ELECTRIC CABLES AND CORDS

Pattern.	Type.	No. of Cores.	Size of Conductor.		Dia. of Conductor.	Diameter over Dielectric.		External Diameter of Finished Cord.	Colours of Cores.	Max. Resistance per 1,000 Yds.	Approx. Max. Current (Amps. Drop per Yard).	Approx. Weight per Foot.
			No. of Wires.	Inch.		Inch.	Max.	Min.				
Uniflex	{ Glazed cotton flexible *	1	23	0.0076	0.044	0.116	0.110	0.14	...	24.4	4	0.011
Duflex		2	23	0.0076	0.044	0.116	0.110	0.28	R. B.	25.7	4	0.022
Quadriflex		4	23	0.0076	0.044	0.116	0.110	0.32	R. B. B. Y. G.	25.7	4	0.043
Sextoflex	"	6	23	0.0076	0.044	0.116	0.110	0.38	R. B. Y. G. B. G. Y. W. Bl.	25.7	4	0.07
Durotwist	Workshop flexible	2	23	0.0076	0.044	0.116	0.110	0.325	...	25.7	4	0.028
Durocirt	"	2	23	0.0076	0.044	0.116	0.110	0.30	R. B.	25.7	4	0.034

When ordered for Ignition Service the outside colouring should be Blue (B.).
 When ordered for Wireless Service the outside colouring should be Red (R.).

* A conductor of 40 0.0076 (which has the same sectional area) may be used for this cable.
 0.0076 inch diameter is equivalent to No. 36 S.W.G., and 0.010 inch diameter is equivalent to No. 33 S.W.G.

When ordered for Telephone Service the outside colouring should be Green (G.).
 When ordered for General Service the outside colouring should be Yellow (Y.).

White = W. Black = Bl.

Def. D.A. (Detachable Data) System
R. B. & Co. Ltd. Patents (privately protected). U.S. Patent applied for

LOW TENSION FLEXIBLE ELECTRIC CABLES AND CORDS—Continued

Pattern.	Type.	No. of Cores.	Size of Conductor.		Dia. of Conductor.	Diameter over Dielectric.		External Diameter of Finished Cord.	Colours of Cores.	Max. Resistance per 1,000 Yds.	Approx. Max. Current (1/2 Volt Drop per Yard).	Approx. Weight per Foot.
			No. of Wires.	Dia. of Wire.		Inch.	Mm.					
Unimag	Protective sheathed flexible cable	1	23*	Inch. 0.010*	Inch. 0.054	...	...	Inch. Max. 0.215 Min. 0.195	...	Ohms. 14.1	Amps. 7	Lb. 0.029
Unigen	"	1	64†	0.010†	0.091	...	...	0.255 0.235	...	5.11	19	0.049
Durex	"	2	23	0.0076	0.044	0.116	0.110	0.39 0.37	R. B.	25.7	4	0.080
Dublin	"	2	23*	0.010*	0.054	0.128	0.122	0.42 0.40	R. B.	14.8	7	0.098
Dual	"	2	64†	0.010†	0.091	0.173	0.167	0.51 0.485	R. B.	5.36	19	0.159
Tribal	"	3	23	0.0076	0.044	0.116	0.11	0.415 0.39	R. B. G.	25.7	4	0.090
Trident	"	3	23*	0.010*	0.054	0.128	0.122	0.44 0.415	G. B. G.	14.8	7	0.112

* A conductor of 40.0.0076 (which has the same sectional area) may be used for this cable.
 † A conductor of 110.0.0076 (which has the same sectional area) may be used for this cable.
 ‡ Natural colour.

0.0076 inch diameter is equivalent to No. 36 S.W.G., and 0.010 inch diameter is equivalent to No. 33 S.W.G.

LOW TENSION FLEXIBLE ELECTRIC CABLES AND CORDS—Continued

Pattern.	Type.	No. of Cores.	Size of Conductor.		Dia. of Conductor.		Diameter over Dielectric.		External Diameter of Finished Cord.		Colours of Cores.		Approx. Max. Current (1/2 Volt Drop per Yard).		Approx. Weight per Foot.
			No. of Wires.	Inch.	Inch.	Inch.	Max.	Min.	Inch.	Max.	Min.	Max. Resistance per 1,000 Yds.	Ohms.	Amps.	
Tripod	Protective sheathed flexible cable	3	64†	0.010†	0.091	0.173	0.167	0.51	0.51	0.51	R. B. Y.	5.36	19	19	0.187
Quadroon	"	4	64†	0.010†	0.091	0.173	0.167	0.51	0.51	0.485	(B. Y. R. G. R. B. G. Y. W.)	5.36	19	19	0.162
Quintomag	"	5	23* 23*	0.0076 0.010*	0.044 0.054	0.116 0.128	0.110 0.122	0.495	0.52	0.495	R. B. G. Y. W.	25.7 14.8	4 7	4 7	0.156

* A conductor of 40 0.0076 (which has the same sectional area) may be used for this cable.

† A conductor of 110/0.0076 (which has the same sectional area) may be used for this cable.

* Natural colour.

0.0076 inch diameter is equivalent to No. 36 S.W.G., and 0.010 inch diameter is equivalent to No. 33 S.W.G.

De-Dei (Touchable Data) System

R. Boring Mathews Patent (provisionally protected) U.S. Patent applied for.

AIRCRAFT INTERNAL COMBUSTION ENGINES

GENERAL DATA

Classification and Cycles—Weights and Consumptions—Horse-Power Formulae—
Variation of B.H.P. with R.P.M. and Altitude—An Engine Design Analysis—
Engine Care and Maintenance.

ALL the engines used for the propulsion of aeroplanes are of the internal combustion class, and the fuel employed is in almost every case petrol. It is possible, however, that other fuels may come into use in the future.

Internal combustion engines may be classified as follows :—

1. Engines operating on constant volume cycle.
2. Engines operating on constant temperature cycle.
3. Engines operating on constant pressure cycle.

Of these, the last class is the most promising, but the constructional difficulties on a commercial basis are not yet solved. The special advantages of a constant pressure cycle, as compared with other cycles, are that low grade fuels can be used ; at all loads the engine is more efficient thermally ; it has a greater overload capacity ; the exhaust heat can be utilised ; the operation is smoother ; and it can be used in a two-stroke type of engine.

Cycle of Operations.—However, the only practicable commercial engine at the present time is of the first-named class, or constant volume cycle. Almost without exception modern engines are of the single-acting type, in which driving impulses are received on one side of the piston only. The cycle of operations in the cylinder is either the four-stroke (or Otto cycle) or the two-stroke cycle ; at present the greater number of engines work on the four-stroke system, in which there is one driving impulse on the piston in every four strokes, or two revolutions, as follows :—During the first, or *induction* stroke, the exhaust valve is closed, and the explosive mixture of air and petrol vapour is drawn into the cylinder through the open inlet valve by the suction of the descending piston ; during the second, or *compression* stroke, both valves are closed, and the mixture is compressed by the ascending piston into the clearance space in the "combustion head" ; at, or just before, the end of the compression stroke the mixture is fired by an electric spark, and the

expanding gases drive the piston down during the third stroke, known as the *explosion*, *expansion*, or *power* stroke, both valves remaining closed; just before the end of the power stroke the exhaust valve opens, and remains open during the whole of the fourth, or *exhaust* stroke, while the ascending piston drives the burnt gases out of the cylinder. The cycle then recommences with another induction stroke.

Timing.—To ensure correct running of an engine the points of opening and closing of the valves, and the points at which ignition occurs must be arranged accurately; this is termed "timing." The principles stand good for practically any engine.

1. The inlet valve is timed to open at approximately T.D.C., but this may be retarded a little (5° - 9°) in some engines for the purpose of making a slight vacuum effect, and so give a greater initial impetus to the incoming gas.

2. The inlet is invariably timed to close some little distance late, i.e., about 18° - 40° after bottom dead centre.

This arrangement is necessary to obtain the maximum amount of gas in the cylinder. At high speeds the piston descends at a greater speed than the gas can enter the cylinder, hence when the piston is at the bottom of the induction stroke gases are still entering through the valve to fill the space evacuated by the piston. Further, in an induction pipe the gases develop a motion, and continue entering the cylinder after B.D.C. The inlet valve is therefore timed to close at a point where the pressure caused by the velocity of the gases is equal to the compression being raised in the cylinder. It will be seen therefore, that the faster the engine is designed to run, the greater will be this angle.

3. The exhaust valve is timed to open approximately 45° - 75° before B.D.C. on the "power stroke." This is done to relieve the pressure, so that no undue resistance will be offered to the piston, as it rises on the exhaust stroke.

4. The closing of the exhaust valve is timed approximately at T.D.C.

5. In order that the force of the explosion be exerted at the correct moment, it is necessary to time the spark to occur a few degrees before T.D.C. The reason for this being that a certain amount of time is required for the combustion to spread over the whole volume of gas.

Within the last two years enormous strides have been made in the subject of valve timing, and in one instance the B.H.P. of an engine has actually been raised some 40 per cent. by improved designs of cams, valves, and springs.

Two-Stroke Cycle.—Up to the present no engine of this type has been successfully used in aircraft. There is, however, a future for it, and considerable experiments are being carried out in this direction.

Reliability.—The most important matter in connection with an aeroplane engine is reliability, combined with comparatively light

weight. There is already among manufacturers a tendency to strengthen up their engines at the cost of some extra weight, and this is undoubtedly a step in the right direction. Moreover, the question of fuel economy is becoming hourly of more importance, since for a long journey a heavier but more economical engine often weighs considerably less than one of the extremely light and extremely wasteful engines still in use, if the weight of the oil and petrol required for each is taken into account.

621.431.3.0244

Pressure Gauges.—The great majority of these are made on the Bourdon principle, with a curved, flattened, phosphor bronze tube. It is usual to make air-pressure gauges with an eccentric scale, and oil-pressure gauges with a concentric scale, so that they may be readily distinguished.

621.431.75

TYPES OF AIRCRAFT INTERNAL COMBUSTION ENGINES

Classification.—Existing engines may be divided into five main classes:—

1. **Vertical Type**, usually 6, but sometimes 4, 8, or even 12 cylinders in a line, with one crank for each cylinder (water cooled).
2. **Vee Type**, with 8 or 12 cylinders per unit, arranged in two rows, at 60 or 90 deg., with one crankshaft, and one throw for each opposite pair of cylinders (water or air cooled).
3. **Double Vee Type**; this design has lately been adopted, and has met with considerable success: it has 18 cylinders, set in three rows 40 deg. apart, and this type is often referred to as the "Broad Arrow" type, and is denoted ψ (water cooled).
4. **Radial Type**, with 7, 9, 10, or 14 cylinders, set in one or more planes. The crankcase is stationary, and the cylinders radiate in the form of a star (air or water cooled).
5. **Rotary Type**, 7, 9, or 11 cylinders in one plane. Crankshaft forms support for engine, and is the only stationary part. Cylinders arranged in form of star round crankcase, and the whole mass rotates round the single crankpin (air cooled).

Type 1 has the lowest head resistance, followed next by the Vee pattern, while the rotary engine offers the highest resistance.

Overhead valves are now fitted to most engines on account of their greater efficiency.

As regards efficiency in fuel consumption per B.H.P., the water-cooled engine is considerably in advance of the air-cooled type. Again, it can be satisfactorily constructed in much larger horse-powers than in the case of the rotary engine. In fact the latter would already have been extinct had it not also been considerably

improved. It is still forced to remain in the background, as it is only being used at the moment, to any extent, for smaller aeroplanes, as the available power of suitable engines does not exceed 200 B.H.P. A rotary engine can be removed from a machine and replaced by another in less than an hour, whereas the replacement of a water-cooled engine is a matter of several hours.

WEIGHT COMPARISON OF VARIOUS TYPES

Type.	Total Weight of Engine in Lbs. per B.H.P.		
	Dry.	In Running Order.	With Tanks and Fuel and Oil for 6 Hrs. Run.
Vertical - -	3.32	4.17	7.86
Vee (water cooled)	2.31	3.13	7.04
„ (air cooled) -	4.22	4.22	8.8
Double Vee (or broad arrow)	1.82	2.47	5.99
Radial - -	1.70	1.70	5.52
Rotary - -	2.56	2.56	7.55

These figures are based on engines of 150 to 250 B.H.P. For larger engines there is a slight reduction in the Wt/B.H.P. ratio.

621.431

Power of Engines.—The total weight of the power plant must be kept down as low as possible so that the manœuvring qualities of the aeroplane may be satisfactory.

Improved performance may be anticipated up to 600-700 H.P. on small fighters. The improvement in the case of increase from 300 to 400 H.P. is negligible.

In the case of large bombing aeroplanes or flying boats, a high powered engine is advantageous, providing the airscrews can be made to deal with the power economically. At over 700 H.P. the loss in airscrew efficiency more than counterbalances the gain due to the larger power units.

HORSE-POWER UNITS

621.431

AIRCRAFT ENGINE EVOLUTION

	Year.	Horse-Power.	Total Weight.	Weight per H.P.	Lbs. Fuel per B.H.P.-Hour.
Langley-Manly engine -	1901	52	Lbs. 151	Lbs. 2.9	...
Original Wright Bros.	1903	12	152	12.7	0.8
Improved " " "	1904	16	180	11.4	...
" " " "	1905	19	180	9.5	...
Redesigned " " "	1908	35	182	5.5	...
Average engine available	1910	54	309	5.7	...
A leading British engine	1913	147	720	4.9	...
Average engine available	1914	112	437	3.9	0.65
" " " "	1915	133	512	3.8	...
" " " "	1916	185	570	3.1	...
" " " "	1917	243	693	2.8	0.55
Liberty '12 cylinders	1917	400	801	2.0	...
" " " (March)	1918	432	808	1.9	0.50
" " " (May)	1918	450	825	1.8	0.46

In 1913, 18.375 B.H.P. per cylinder was counted good practice ; the 1918 (May) Liberty engine developed 37.5 B.H.P. per cylinder of the same bore and stroke (5 in. x 7 in.).

Foot-pound.—In Great Britain the unit of work or energy is the foot-pound, being the work done by a force of 1 lb. exerted through a distance of 1 ft.

Kilogramme-metre.—On the Continent the unit of work or energy is the kilogramme-metre, being the work done by a force of 1 kg. exerted through a distance of 1 m.

(1 foot-pound=0.138 kilogramme-metre.)

Horse-Power.—In Great Britain the unit of power is the horse-power, which represents the performance of work at the rate of 33,000 ft.-lbs. per minute, or 550 ft.-lbs. per second.

Cheval-vapeur.—On the Continent the unit of power is the cheval-vapeur or metric horse-power, which represents the performance of work at the rate of 4,500 kg.-m. per minute.

(1 horse-power=1.014 cheval-vapeur.)

Indicated Horse-Power.—The horse-power developed in the engine cylinders is proportional to the force exerted on the pistons during the working stroke, and to the distance travelled by the pistons in feet per minute.

The force exerted on each piston is the product of the average effective pressure of the gas per square inch and the area of the piston in square inches.

If d = the diameter of the cylinder in inches,
 D = the diameter of the cylinder in millimetres,
 s = the stroke in feet,
 S = the stroke in millimetres,
 n = the number of revolutions per minute, at maximum speed,
 p = the average effective pressure on the pistons in pounds per square inch,
 N = the number of cylinders.

Then—

The force exerted on the pistons = $7854d^2 \times p$.

The distance travelled by the pistons in feet per minute = $2sn$.

To get the I.H.P. the product of these two quantities is divided by 4, because in the Otto cycle the force acts on the pistons for only one-fourth of the distance travelled, multiply by N , the number of cylinders, and finally divide by 33,000, the number of foot-pounds per minute for each horse-power.

Then—

$$\text{I.H.P.} = \frac{7854d^2p \times 2sn \times N}{4 \times 33,000}$$

If it is assumed that a mean effective pressure p of 90 lbs. per square inch is obtained in the cylinders, and that the distance travelled by the pistons $2sn$ is 1,000 ft. per minute, the above expression becomes:—

$$\text{I.H.P.} = 0.5d^2N \text{ approximately.}$$

Brake Horse-Power.—The foregoing gives the I.H.P., that is, the power developed in the engine cylinders, but a certain amount of the power is dissipated in the friction and inertia of the pistons, valves, bearings, etc., and as a consequence the actual power available for driving the propeller is considerably less. It is usual to reckon the power that is lost at 20 per cent. Accordingly the horse-power which can actually be utilised may be taken at about 80 per cent. of the I.H.P. This actual horse-power is termed the brake horse-power, written B.H.P., because it represents the power which is obtained on test when a brake is employed to absorb all the useful power of the engine.

Allowing that the B.H.P. is only 80 per cent. of the I.H.P., the formula for the B.H.P. is:—

$$\text{B.H.P.} = 0.4d^2N,$$

or where the diameter is taken in millimetres—

$$\text{B.H.P.} = 0.0621D^2N.$$

This corresponds with the rating for B.H.P. adopted by the Royal Automobile Club, and forms a very convenient and simple formula to represent the approximate power which the engine may be expected to give.

It will be understood, of course, that if the engine works on a two-stroke cycle the B.H.P. will be rather less than twice as great as is given by the above formula.

The above formula is that also adopted in the Treasury Regulations for calculating the horse-power of motor cars, except that it is expressed a little differently, in that a division of 2.5 is employed instead of a multiplier of 0.4.

In the foregoing formulæ the distance travelled by the pistons is to be assumed to be 1,000 ft. per minute, but for cases in which this does not hold good a correction is necessary. In calculating the power of petrol engines, the pressure obtainable in the cylinder is estimated to be independent of the speed. This would mean that the B.H.P. is simply proportional to the speed, and this in fact holds good within wide limits.

The following are some alternative formulæ for the approximate estimation of horse-power. R is the ratio s/d :—

$$\text{B.H.P.} = 0.2d^2N\sqrt{s} \quad (\text{Remington}).$$

$$= 0.2d^2.3N\sqrt{R} \quad (\text{Midland A.C.}).$$

$$= 0.5d(d-1)N\left(\frac{2R+1}{R+2}\right) \quad (\text{Callendar}).$$

$$= 0.4d^2NR^{0.4} \quad (\text{O'Gorman}).$$

$$= \frac{0.5d^2N}{\sqrt{\frac{1}{R} + 0.3}} \quad (\text{Lanchester}).$$

$$= 0.197d(d-1)N(R+2) \quad (\text{S.M.M.T.}).$$

$$= \frac{d^2sNn}{75,000} \quad (\text{Marshall}).$$

$$= \frac{D^2SNn}{123,000,000} \quad (\text{Marshall}).$$

The last two formulæ are for aero engines; for motor car engines, with lower mean effective pressure, the divisors are 12,000 and 200,000,000 respectively.

"Another good rule for aero engine is 18 to 21 B.H.P. per litre engine capacity per 1,000 cycles (2,000 r.p.m.), with a m.e.p. of 64.5 lbs. per square inch."—*Coatalen*.

B.H.P. AND CYLINDER CAPACITY

Type of Engine.	B.H.P. per 1,000 c.c.	R.P.M.
Low speed -	6	1,000
Motor car -	7.9	1,000-1,300
Racing car -	8.9	1,000
" -	14-18	2,000
" -	27-28	3,000-3,200
Aero -	18-21	1,500-2,000

VARIATION OF H.P. WITH R.P.M.

As an illustration of the variation of the horse-power with the revolutions per minute, particulars are given in the following table of the Curtiss 90 and 160 H.P. and Wisconsin 130 H.P. engines respectively:—

R.P.M.	90 H.P. Engine.	160 H.P. Engine.		130 H.P. Engine.	
	Actual H.P.	Actual H.P.	Torque in Pound-Feet.	Actual H.P.	Torque in Pound-Feet.
1,100	75	144	690	120	585
1,200	81	156	680	132	575
1,230	...	160	674	134	570
		(Rated)			
1,300	87	166	670	142	565
				(Normal)	
1,360	90	...	660	147	563
	(Rated)				
1,400	92	175	650	150	560
	(Normal)	(Normal)			
1,500	98	181	635	158	555
	(Max.)	(Max.)			
1,550	100	184	620	162	550

As a matter of interest, columns have been added to the above table giving the torque in pound-feet of the 160 H.P. Curtiss and the 130 H.P. Wisconsin engines.

Gyroscopic Effect of Rotary Engines.—While a gyroscopic couple exists, it is small compared with the power of the flying controls that are available, and hence is usually neglected in calculations.

$$\text{Gyroscopic torque} = 0.0048 \frac{W \cdot r \cdot G^2}{R}$$

v = velocity in feet per second.

G = radius of gyration in feet of the engine about the axis of rotation.

R = radius in feet of the circle in which the aeroplane is turned.

Only base and $\sin$ technical data series

0	6,000	10,000	15,000	20,000
100	82·5	73	62·5	53·5
150	124	110	93·75	80·5
200	165·5	146·5	125	107·5
250	180	160	136	117
300	248	219·5	187·5	160·5
400	331	293	250	214
500	413·5	336	312·5	307·5
1,000	825	730	625	535

The horse-power available depends almost entirely upon the density of the air, and only on its temperature and pressure in so far as the density is affected by them. The r.p.m. of an aeroplane engine, when climbing with its throttle fully open, is practically constant.

This means that as the density becomes reduced, the power likewise falls off proportionately. The density of the air is directly proportional to its pressure, and inversely proportional to its absolute temperature. For further notes on this matter, the reader is referred to the meteorological data in Division 551.591.

Altitude must be regarded as a governing factor in modern aero engine design. It will be observed that engine compressions are increasing, in the effort to obtain satisfactory operation at high altitudes.

"Aircraft engine design resembles motor car engine production in this particular, that it is all the time a question of compromise. The most successful designer is he who exercises the soundest judgment in weighing a hundred and one factors of the hour, and who gives the shrewdest estimate of the relative value of each."
—Coatalen.

A COMPARISON OF MOTOR CAR AND AERO ENGINES

	Motor Car Engine.	Aero Engine.
Prime considerations	Silence and low cost.	Power for engine weight and volume.
Maximum horse-power	Low, often only about 20 H.P.	High, up to 500 H.P. in one engine.
Weight - -	Unimportant, within limits.	Low weight is vital.
Full power operation required	Very seldom.	Nearly all the time.
Normal use - -	Rarely on mountain roads.	Anything up to 20,000 ft.
Temperature -	Gradual changes only.	Rapid changes from normal to below freezing.
Lubrication - -	Crank-case base-chamber suffices.	Dry sump system necessary.
R.P.M. - -	Wide, limits up to 3,400 r.p.m. for racing engine.	Limited to about 2,000 in case of direct drive airscrew. (Reduction gear required for higher speeds.)
Torque - -	A constant torque required from 300 to 2,000 r.p.m.	A maximum torque required at practically one speed only.
Compression -	Low (m.e.p. about 80 lbs. per square inch).	High (m.e.p. from 87 to 132 lbs. per square inch).
Valves - -	Side, as more silent.	Overhead, as more efficient, though more noisy.
Silence - -	Important.	Hardly considered, especially as the airscrew makes so much noise.
Labour - -	Essentially a minimum.	Not deciding factor. Low weight and fuel consumption more essential.
Economy in fuel and oil	Not important.	Vital.
Cost - -	A minimum, so machining economised.	Not deciding factor. Low weight and fuel consumption more essential.

*Patent applied for
 D.L. 11 (Lubrication Drive System)
 R. B. & Co. Patents (provisionally protected) U.S. Patents applied for*

AN ENGINE DESIGN ANALYSIS

(Based upon a large number of examples)

Item.	Minimum.	Maximum.	Average.
Mean effective pressure, lbs. per sq. in.	87	...	...
Compression ratio - - -	4.25	...	...
Piston speeds, ft. per min. - -	1,280	2,100	1,700
Bore and stroke ratio - - -	1.08	1.66	1.4
Revolutions per min. - - -	1,200	2,000	1,800
Gear reduction - - -	0.6 : 1	2 : 1	2 : 1
Aircrew, direct drive, revs. per min.	1,200	1,500	1,250
Aircrew, gear drive, revs. per min.	900	1,180	1,000
<i>Water-Cooled Engines—</i>			
Petrol consumption, pints per b.h.p.	0.516	0.66	0.6
lbs. - - -	0.465	0.6	0.54
Oil consumption, pints per b.h.p. -	0.012	0.07	0.03
lbs. - - -	0.0137	0.08	0.034
Petrol and oil consumption combined - - - pints per b.h.p.	0.54	0.7	0.62
" " " lbs. per b.h.p.	0.49	0.63	0.57
Mean effective pressure, lbs. per sq. in.	80	...	...
Compression ratio - - -	3.8 : 1	...	4.8 : 1
Bore and stroke ratio - - -	1 : 1	1.66 : 1	1 : 1.3
Piston speed in ft. per min. - -	1,050	2,100	1,800
<i>Rotary Engines—</i>			
Petrol consumption, pints per b.h.p.	0.6	0.91	0.75
lbs. - - -	0.54	0.82	0.68
Oil consumption, pints per b.h.p. -	0.067	0.18	0.14
lbs. - - -	0.075	0.2	0.16
Petrol and oil consumption combined - - - pints per b.h.p.	0.67	1.07	0.85
" " " lbs. per b.h.p.	0.62	0.99	0.79
Mean effective pressure, lbs. per sq. in.	60	90	80
Compression ratio - - -	3.75 : 1	...	4.5 : 1
Bore and stroke ratio - - -	1.13 : 1	1.46 : 1	1.3 : 1
Piston speed in ft. per min. - -	1,100	1,475	1,200

Engine Supports.—The American S.A.E. recommends the following table of dimensions, omitting all reference to sizes of bolts:—

Distance between bearers	-	-	12	14	16 in.
Width of engine bearers	-	-	2	2½	2½ „
Distance between centre of bolts	-	-	14	16½	18½ „

As yet, unfortunately, there are no British standards. This results in considerable trouble in fitting engines into various aeroplanes, and the matter therefore needs attention.

Compression Ratio.—As will be observed upon reference to the engine design table (on previous page), the compression ratio of a modern aero engine varies. The ratio of 4.25 corresponds to 85.3 lbs. pressure per sq. in. (or 100 lbs. absolute). The compression pressure with certain fuels, such as alcohol, can be raised to as much as 200 lbs. per sq. in. (about double that of petrol) before pre-ignition takes place.

Brake Thermal Efficiency.—A horse-power hour = $33,000 \times 60$ ft.-lbs., and since a British thermal unit (B.Th.U.) is 778 ft.-lbs., a horse-power hour = $\frac{33000 \times 60}{778} = 2545$ B.Th.U.

$$\text{Brake Thermal Efficiency} = \frac{2545}{\text{B.Th.U. of fuel per lb.} \times \text{No. of lbs. of fuel}}$$

This value varies in value from 0.20 to 0.27 at full load. (The latter means a very low consumption of fuel, say about 0.47 lb. of petrol per B.H.P.-hour.)

Ball Bearings

Crushing load $P = 82,400 n d^2$, n = number of balls, d = diameter of each ball.

Diameter in inches	-	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{2}$
Crushing load (lbs.)	-	1,288	2,900	5,150	8,050	11,600
Working load (lbs.)	-	160	360	640	1,000	1,450

ENGINE CARE AND MAINTENANCE

By this expression is meant the adjustment of an engine so that the output may be a maximum, the revolutions steady and under control, and the efficiency at its best for the conditions of operation. The tuning of an aero engine is similar to that of a racing motor car engine.

Erection.—When fitting an engine to an aeroplane, it is of the utmost importance to make sure that it is not strained in any way, or it will not operate to best advantage. The bed upon which it is set must be dead true on its surface, and the foundation bolts must

be most carefully tightened on opposite sides in turn. The makers of most engines issue instruction books, which should be carefully perused before handling the engine, and especially before dismantling. Aero engines are, as a rule, so compact that they are delivered as tested at the maker's works, therefore everything may be assumed to be in order, if the lubrication receives proper attention, and the various coupling pipes are tightly connected up.

Direction of Revolution.—When it is desired to ascertain the direction of rotation of an aeroplane engine, it should be turned by hand, and if the inlet valve of any cylinder opens immediately after the exhaust valve of the same cylinder closes, it will be known that the engine is being rotated in the direction in which it is designed to run. By noting the order of opening of the inlet valves, the order in which the cylinders fire can be ascertained. An engine should always be timed by the closing of the inlet valve, and the opening of the exhaust valve, as these are points that can easily be observed. It must be borne in mind that the timing will be affected if the tappet clearance is permitted to become greater than normal.

Valve settings should always be taken with the engine turning in its normal direction, so that any errors may be avoided due to the play in the various gear wheels, etc.

Inspection.—As soon as possible after completing a day's work, the engine should be carefully inspected; however, care must be taken that adjustments are not made unless really necessary.

After a clean down, it is wise to lubricate and grease all parts ready for the next day's flight. Any source of oil leakage should be investigated.

It is of the utmost importance that all oil and grease should be kept clear of any electric cables. The length of the latter should be as short as possible, and they should be so fitted, preferably in fibre tubes, that there is no possibility of damage by chafing or heat.

After every twelve hours' running at most, the lubricating oil should be drawn off, and the crank-case washed out with paraffin (petroleum) oil to remove all dirt and sediment, the engine being then given about a dozen sharp turns. The paraffin is then emptied out and replaced by the correct quantity of lubricating oil.

Upon completion of about 150 hours' running at most, in the case of a water-cooled engine, or after twenty hours in the instance of a rotary air-cooled engine, the engine should receive a very thorough examination and decarbonising, for with every precaution in design an aeroplane engine is a very sensitive machine, that in use is constantly operated at full load. The compression must, first of all, be very carefully tested by Taylor's Okell tester or some similar instrument, and if not between 90 and 95 lbs. per sq. in. on a water-cooled engine, it will be necessary to grind in the valves, more particularly the exhaust valve, and adjust the tappets accordingly. The cylinders and piston heads must be carefully cleaned of any sign of carbon deposit, and all oil passages carefully cleared

out. The valve springs should be examined from time to time, as any loss of tension causes erratic running. Valve levers, plungers, etc., should be tried occasionally to make sure that they are working truly and quite freely.

When a water-cooled engine has been in service for 300 hours as a maximum, it should be entirely dismantled for examination and overhaul. This work is best carried out by the makers, as they have every facility for the work, including Froude water brakes or other suitable dynamometers for accurately testing the brake horse-power of the engine, and so ascertaining that the engine is operating at its best output.

Switches.—It is the general practice to fit tumbler switches so that "UP" is in the running position and "DOWN" is off.

Effect of Altitude and Low Temperature.—As the altitude increases the power of an engine decreases, owing to the rarefaction of the air. A difference in height of 10,000 ft. reduces the engine power by almost 25 per cent.

If a given motor consumes 230 gm. of petrol per horse-power hour at the ground level, at a height of 2,000 m. it will increase this consumption to 260 gm. without a corresponding increase of power. Hence a device should be fitted to reduce the pull on the jet. In the case of the special Zenith carburettors used for the Salmson and Renault engines, extra air valves are incorporated as a standard; in the first-named as a part of the induction pipe, and in the latter on the carburettor itself. In the Renault-Zenith carburettor the air inlet is also regulated by a throttle valve, which is calibrated in accordance with varying heights.

In very cold weather there is also a tendency for the lubricating oil to thicken. The remedy for the latter is to start with hot oil in the oil system, and in the case of the rotary engine add about 5 per cent. of methylated spirit to the supply tank. The latter should always be placed in as unexposed a position as is feasible.

Hints on Engine Operation.—By systematic procedure and careful analysis of difficulties the starting and running of a petrol engine may be rendered quite simple and easy. It must be admitted that the petrol engine has a fickle and delicate temperament, so it must be humoured, for it is affected for better or worse by heat and cold; wetness and dryness; variations of barometric pressure and altitude; and variations in the density of the fuel employed.

Running Hints

1. Always give the engine time to warm up before opening the throttle wide. The reason for this is that carburation cannot possibly be effected correctly if the engine is not warm. Further, the oil must have time to "thin out," or an unduly high pressure will result in the system.

2. Watch instruments carefully to note undue rise in temperature or oil pressure, or fluctuation of revolutions.

3. Never slam the throttle in either direction. This is a golden rule, even in cases of emergency, as an engine will always respond quicker when treated correctly; rapid opening of the throttle may cause the engine to "choke."

4. The engine must not be run at its maximum revolutions for more than a minute, and then only very occasionally.

5. Always regard the engine as one would a living person—the best pilots are those who can coax the best out of an engine, or nurse it when it is in trouble.

As a rule, it may be taken, if difficulties arise, that it is not due either to the magneto (except possibly the contact points and brushes) or to the setting of the jets of the carburettor, hence it is most unwise to tamper with these, as a general rule, until other expedients have first been tried. The most likely sources of starting or running troubles are the sparking plugs, insufficient heating, incorrect setting of throttle, or spark advance.

To assist in a diagnosis of a troublesome case, the following system of analysis has been prepared. It is assumed that reference will be made to the previous sections of this division for detailed information concerning certain points, such as carburation, ignition, sparking plugs, etc.

Starting the Engine

I. Preliminary.

Inspect generally.

Lubricate where necessary, and not to excess.

Test oil level in engine sump.

Fill reserve oil tank through wire strainer funnel (see that the correct oil is used).

Replace tank cover, and see that vent hole is clear.

Fill petrol tank through a strainer funnel. Note whether fuel is free from drops of water.

Replace tank cover, and see that vent hole is clear, if gravity system. If pressure supply, pump up if required.

Examine the petrol strainer at the carburettor to see that it is clean.

II. When Ready to Start.

Steadily raise the needle of the carburettor (do not tickle it) until flooding just commences (an excess may give too rich a mixture for starting). With rotary engines, failure to start is far more frequently caused by excessive petrol rather than with too little.

If the carburettor will not flood, ascertain and remove the cause of the stoppage of the petrol supply. (Note: an indiarubber connecting pipe often frays at the ends, and blocks the metal tubes it connects.)

Retard the spark lever to the normal starting position, as ascertained by experience.

Close the throttle and then bring the lever *back* to the normal starting position (thus taking up any slack in the rods and pins so that the position is constant). The normal starting position is sometimes, or should be, clearly marked on the quadrant.

Turn engine through several revolutions with the magneto switch off.

If the engine turns stiffly, inject a little paraffin (petroleum) oil into each cylinder through the exhaust valves to soften the congealed lubricant, which is probably the cause of the difficulty. Too much paraffin or petrol may wash away the lubricant altogether. Some engines need the injection of a little lubricating oil, especially if the cylinders are comparatively small.

If still very stiff to turn, make a careful inspection for a mechanical fault.

Open magneto switch.

Start by aid of hand magneto, self-starter, or by swinging the propeller in the proper direction of rotation. In the case of starting the engine by swinging the propeller, the attendant who is at the propeller should always be warned by word of mouth when "contact" is made by putting the switch in the "on" position.

If the engine fails to start, switch off immediately, flood carburettor again (taking care, especially in the case of rotary engines, not to flood too much), turn the engine over, switch on, and attempt to start again, if possible, with a quicker turn so as to obtain a better spark. When stiff, an engine is often not turned fast enough to get a good spark. If the engine is choked give a few revolutions of the airscrew in the direction reverse to running, with the magneto switch and petrol turned off.

When the Engine Starts

Advance the spark and adjust the throttle so that the engine does not race, and allow it to run slowly for a few minutes to warm it up to a normal working temperature.

Then test the engine for acceleration and deceleration, listening for any unusual sound. If the engine is fitted with aluminium pistons, the engine will be noisy until warm.

Observe the exhaust to see that it is not black or flaming, due to excess of petrol, or blue, due to excess of lubricating oil. Until the engine has warmed up properly, there is often a little white steam vapour.

Test restarting, and then the engine will be ready for flight.

If Engine Does not Start

I. If it usually starts easily, check over the preliminary instructions to see that they have all been complied with.

Turn engine and ascertain, by aid of an insulated handled metal tool, if a spark is produced at each plug. If not, examine insulated leads from the magneto (to see that there is no breakage or leakage),

the earthing switch (to see that there is no earth connection), the distributor (this may be damp or dirty), and the magneto contact-breaker.

If no signs of an explosion on first attempts to start, examine sparking plugs, as they are the most likely cause of the trouble. Dip in petrol to remove moisture, clean and adjust gap if necessary (refer to the section of this division *re* sparking plugs).

Take out carburettor main jet to see whether it is free of water and dirt. Empty float chamber to get rid of water.

Slightly vary the throttle position; if a Zenith carburettor, listen for the characteristic suction whisper which occurs on turning the engine when the throttle is correctly set.

If the engine is warm it may need a slightly greater throttle opening.

If preliminary flooding seems excessive, so that there is a possibility of the mixture having been too rich, open the throttle and give several turns to the engine, so that a new beginning may be made.

II. A Strange Engine.—If the engine will not start after taking the steps set forth in (I.), and especially if little is known about the individual engine in particular—

Examine slow running setting of carburettor to see that it is not choked, and whether or not it is correctly set.

Close air inlet of carburettor partially to increase the velocity of the air, and so strengthen the mixture.

Prime each of the cylinders, through the exhaust valves or sparking plug openings (or priming cocks, if fitted), with a little petrol.

Search very carefully for an air leak between the carburettor and the engine. Also see that sparking plugs, valve caps, valve guides, etc., are perfectly air-tight.

Stops after Starting

If it starts at slow speed and then stops, probably the throttle was not open wide enough before starting.

If it starts satisfactorily and then stops after a few minutes, especially in cold weather, note whether there is a dewy deposit or hoar frost on the induction pipe; if so the jet has probably been choked with hoar frost or ice. To obviate this, open the throttle a little wider than usual, as soon as the engine starts, so as to warm up the induction pipe and carburettor. The engine cannot do any work until the induction pipe has warmed up sufficiently to avoid this condensation.

If a cold engine slows down evenly while running light, the mixture is too rich, or—

If a warm engine slows down unevenly, the mixture is too rich, and the slow-running device must be adjusted to give less petrol.

If the engine runs erratically, there is probably an air leakage

between the carburettor and the cylinders, or else petrol has collected in hollows in the inlet pipes. If the throttle is closed further, instead of continuing to run erratically, the engine usually stops, which confirms the above diagnosis.

If the engine slows down evenly when warm, but when cold soon stops, and will not run at slow speeds, the mixture is too weak, and so the slow running device must be adjusted to give more petrol, or a larger auxiliary jet must be fitted.

Engine does not Accelerate Well

If popping noises occur in the carburettor, the engine is probably too cold; the induction pipe insufficiently heated; or the mixture too poor (indicating necessity for a larger auxiliary or compensating jet). Refer to the section of this division dealing specially with carburettors.

Engine Misfires

(I.) *If regularly*, the fault is due to either—

- (a) Sooted or cracked plugs.
- (b) Dirty contacts on the distributor.
- (c) A short circuit on one or more high tension wires.
- (d) A valve or valves sticking.
- (e) The valve clearances being too small or too great.
- (f) An air leak past a valve stem.
- (g) A roughness on the contact breaker of the magneto, or a swelling due to damp of the contact breaker fibre bushing.

(II.) *If intermittently*, the trouble is probably caused by—

- (a) A piece of dirt in the carburettor jet; this must be carefully cleaned out, as sometimes the dirt falls back into the base of the jet, only to cause the same trouble later.
- (b) Water in the carburettor. The only remedy is to empty the carburettor. Always filter petrol into the main tank very carefully to strain off the water.
- (c) Water or loose dirt may have got on to the distributor.
- (d) A short circuit on one of the high tension wires or loose connection.
- (e) Valves being incorrectly timed, or the timing gear loose.

Engine does not Attain Normal Speed

If the engine does not attain its proper speed, either—

- (i.) The mixture is too poor, and a larger main jet must be fitted.
- (ii.) The mixture is too rich, and a smaller main jet should be tried.
- (iii.) The choke tube is too small.
- (iv.) The engine is cold, and the air intake insufficiently heated.
- (v.) Insufficient air (due to the main airtake being restricted).

- (vi.) Incorrect ignition timing.
- (vii.) The compression is poor.
- (viii.) Valve springs too weak. This is a frequent source of trouble, and is most difficult to diagnose.

OVERHEATING

I. The Engine Overheats.

This is usually accompanied with a smell of burnt oil.

The most likely cause is insufficient advance of the ignition.

The radiator may be short of water, clogged up, or of insufficient capacity. Shortage of water may be due to excessive evaporation, the reason for which must be investigated. It may only be due to leakage.

The mixture may be too rich, causing a slower burning mixture and consequent transmission of more heat to the jackets. To remedy, the jet must be changed for a smaller one.

Insufficiency or poor quality of the lubricating oil in the crankcase will also cause overheating.

Examine the water, the oil filters, and the oil pumps to see that they are functioning properly.

There may be too much back pressure.

If there is a silencer, it may be choked, and so cause overheating. (Owing to the increased horse-power required when a silencer is fitted, it is very rarely that an aircraft engine is nowadays equipped with one, though a number of machines were so fitted before the war.)

The timing of the valves may be incorrect.

II. The Exhaust Pipe Overheats

With spark too much retarded.

Too rich a mixture.

Insufficient lift of exhaust valves.

The Engine Makes an Unusual Noise

I. Pre-Ignition Knocking.

A characteristic pinking noise indicates that the spark is too far advanced.

If this noise occurs before the engine gives its normal maximum output, with spark in usual position, it is due to pre-ignition caused by carbon deposit in the cylinder, on the pistons and valves.

If the engine is imperfectly cooled, the water circulation obstructed or defective, or the water has run short, pre-ignition takes place.

If a sparking plug leaks, knocking takes place.

If the mixture is too weak, knocking is also liable to occur.

II. Noises due to Mechanism.

Upon the detection of a knock, grind, rattle, or squeak, if possible, the engine should be at once stopped and a careful examination made, as such an inspection may save the engine from serious damage.

Knocking occurs from loose big end bearings, worn main bearings, loose parts, etc.

Knocking or grinding accompanied by a squeak indicates binding and lack of lubricant.

A dull hammer or slapping noise often occurs before an engine, which is fitted with pistons of different material to the cylinder walls, is warmed up properly, *e.g.*, steel pistons in cast-iron cylinders or aluminium pistons in steel or cast-iron cylinders. This sound also occurs when a piston wears oval. Many cylinders are bored with a slight taper, so as to be parallel when hot; this may give rise to slapping on starting.

A rattle or click may be generally traced to valve stems, cam followers, and tappets, or else to loose nuts.

Note.—When running an aero engine in the air, the first intimation of trouble is usually vibration. In an aeroplane the slightest increase of vibration from the engine is very noticeable. Pilots should cultivate the "feel" of an engine, in order to appreciate any unusual vibration. The noise of the airscrew and of the machine travelling through the air make it practically impossible to note the peculiar little noises which are so readily discernible in a car.

III. A Hissing Noise is generally due to—

- (a) A leakage at an induction pipe joint, or exhaust pipe joint, or very often at the carburettor joint on to the induction pipe.
- (b) A leaking sparking plug joint, or cracked porcelain.

Excessive Petrol Consumption

This may be due to—

- (a) Insufficient advance of ignition.
- (b) Too rich a mixture.
- (c) Insufficient or defective lubrication.
- (d) Leakage of petrol at unions, etc.
- (e) Jets not screwed up properly in the carburettor.
- (f) Induction pipe heating insufficient, necessitating the employment of larger carburettor jets than really necessary.
- (g) Engine compression poor, due to piston rings being loose, or valves not seating properly, and engine in poor condition generally.

Stopping an Engine

Always throttle down to allow a hot engine to run slowly for a few minutes before finally stopping by cutting off the ignition. This ensures the forced circulation of the water till the cylinder walls have cooled considerably.

When stopping an engine close the throttle, and turn off the petrol prior to switching off the ignition.

When shutting down a radial type engine, cut out the ignition before the throttle, so that the engine may stop quickly.

When a rotary engine such as the Gnome is stopped, it should be left so that the lowermost cylinder has the valve open to permit any excess lubricant to drain away.

In the case of the Gnome engine, if the petrol is not turned off when the engine is stopped it may not restart, due to flooding and choking.

An engine which has been stopped on the throttle should not be allowed to stand with the switch on, under any circumstances.

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PETROL CONSUMPTION

The commercial efficiency of petrol engines is expressed in terms of the consumption of petrol per brake horse-power per hour.

As regards the working mixture of petrol and air, the proportions which give the greatest power for a given size of engine are not the proportions which give the lowest consumption of petrol per horse-power.

Generally it is usual in stationary engines to work at high economy rather than at high power, but in aeroplane engines the reverse holds good, it being of more importance to secure large power for a given weight than low fuel consumption.

Accordingly, no particular mixture can be described as the best for petrol engines under all circumstances. For example, in the test of a particular engine the highest power was obtained with a mixture by weight of 1 of petrol to 11.6 of air, while the highest economy, that is the lowest consumption per B.H.P., was obtained with 1 of petrol to 16.9 of air. As the economy rises the power falls, but in practice it is usual to employ mixtures of 1 to 10 or 12 to get maximum power.

For this particular engine the consumption of petrol per B.H.P. per hour varies between 0.614 and 0.75 lb., according as the engine is working at the highest economy or the highest power.

Average consumptions of petrol in the case of modern engines of good design should not exceed :—

For water-cooled engines	0.50 lb. per B.H.P. hour.
„ stationary air-cooled	0.65 „ „ „
„ rotary air-cooled	0.70 „ „ „

PETROL CONSUMPTION OF TYPICAL ENGINES

Horse-Power of Engine.	Gallons per Hour.	Pints per Hour.	Lbs. per Hour
170	12	96	86.4
230	18	144	129.6
360	28	224	201.6

Petrol weighs 7.2 lbs. per gallon.

" " 0.9 " pint.

" " 1 " 1.1 pints.

9.5 in. of petrol = $\frac{1}{2}$ in. of mercury.

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ENGINE DESIGN DETAILS

Diameters of Cylinders.—For all practical purposes, 6 in. is the limit for the bore of any cylinder used on an aero engine. This limitation is imposed by difficulties in cooling, firing, eddy currents, etc.

Number of Valves per Cylinder.—Two exhaust and two inlet overhead valves per cylinder are largely favoured by designers of aero engines. This arrangement permits of good water-cooling, also of the fitting of the sparking plug in a top central, well-cooled position. Other valve arrangements do not allow for this sparking plug position, *e.g.*, the Maybach engine has three exhaust and two inlet valves, with very little water space between the seats. The plug position is necessarily at the side.

Pistons.—The modern tendency is to construct pistons of aluminium alloy. A common fallacy is to assume that aluminium is used on account of its lightness. This is not the case; the reasons for the use of aluminium alloy are :—

- (i.) The pronounced property of conducting heat.
- (ii.) It forms an excellent bearing surface when used in connection with steel cylinders.
- (iii.) It can be made as light as a steel piston.

Aluminium pistons when cold have a very big clearance, and engines fitted with them have a very pronounced slap when cold. This is not a disadvantage, as the pistons rapidly expand to their correct size.

The manufacture of these pistons is very tricky, as aluminium alloy must be carefully heat-treated to prevent "growing."

Connecting Rods.—In the case of many modern aero engines, more than one piston is attached to each crankpin. Owing to the necessity for reduction in weight, it is now usual to employ a main connecting rod, with auxiliary connecting rods for other cylinders, attached to wrist-pins on its big end, instead of embracing it or working on the same crankpin. Since the centres of the wrist-pins upon which these auxiliary connecting rods operate are not coincident with the centre of the crankshaft pin, their movement is along an elliptical, instead of a circular path, thus altering the stroke of the piston attached to the auxiliary rod. This must be allowed for in the design of the engine.

In the case of the double vee Sunbeam engine, the centre row of pistons has a travel of 160 mm., while the travel of the pistons in the side rows is 168 mm. The Napier Lion is also of this type.

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CARBURATION

It is not proposed to enter into particulars as to the detailed construction of various carburettors, as this information can be obtained elsewhere. For the purpose of illustration, however, the chief features of the two types that are principally employed in aero work—the Zenith and the Claudel-Hobson—will be referred to later.

As aero engines are becoming larger in size, a little difficulty arises in carburation, in that the jet orifices tend to be too big for successful atomisation. Hence it is now almost standard practice to employ double carburettors (supplied normally by one float chamber of the ordinary pattern common to both). In fact, it is a good plan to use a separate carburettor for every three or four cylinders. A form of modified double jet seems, even with double carburettors, to be the most satisfactory system, as a better spray effect is obtainable. Absence of moving parts and entirely automatic operation is also a great advantage. Further provision should be made for a small reserve of petrol near the jet to permit a rapid opening of the throttle, and consequent quick acceleration. A slow-running arrangement should also be incorporated, and a filter is of importance, since a choked jet may be a serious matter. All petrol put into the main tank should be carefully strained. Both the Zenith and the Claudel-Hobson carburettors comply very closely with the requirements of an ideal device for aero engine work, though differing in several important respects from each other.

The main characteristic of the **Zenith carburettor** is the fitting of a submerged auxiliary or *compensating jet* in addition to the *main jet*. It also incorporates a *slow running jet*. The function of the compensating jet is to keep the mixture at practically constant strength at all engine speeds, i.e., to correct the irregu-

larities of the main jet. It has the greater influence at low speeds, while the main jet has most effect at high speeds.

The compensating jet nozzle is placed concentrically with the main jet at the bottom of an interchangeable choke tube. A very great advantage of this carburettor is that once it is adjusted it need never be touched again, unless the conditions of service are radically altered, hence it is well worth while taking trouble to tune or adjust it properly.

The bore of each jet, and also of each compensator, is marked on it in hundredths of a millimetre, hence it is essential that it should not be enlarged or reduced, or all the advantage of knowing definitely what size is being used will be lost.

Adjustment is effected by changing the choke tube, the main and compensating jets, and regulating the slow-running device.

The first thing to be decided upon is the choke tube. If too large, the engine will not accelerate properly; if too small, the maximum speed will be too low. Then the main jet is selected by trial at the higher engine speeds, followed by the compensating jet at lower speeds. Finally, the slow-running jet is regulated to ascertain the minimum opening necessary. Further details of these operations are given under the heading "Carburettor Tuning."

The latest type of carburettor provides for rapid throttle manipulation, and is designed to run in almost any position.

The Claudel-Hobson Carburettor, as employed for aero work, is that known as type "Z," which differs in many ways from the earlier instrument known to motor car users, now called type "A." It is automatic in action, once properly adjusted. In principle of design it comprises a submerged *main jet* (with air-ejector nozzle) and a pilot or *auxiliary jet* (also having an air-ejector nozzle), with a variable choke.

Also on the carburettor there are adjustable stops (a) for the drum-type throttle; (b) for a slow running by-pass; and (c) for modifying the choke space in the throttle. The jets are numbered, and vary from each other by one-twentieth part of a millimetre. Adjustment is attained by first testing the *main jet* at high speed with a warm engine, and then by setting the slow-running device. The latter is accomplished, firstly, by the *throttle stop screw*, which regulates the minimum throttle opening, and secondly by the slow running by-pass screw. If there should be indications of incorrect mixture at slow speeds, the screw for modifying the *throttle choke space* should be adjusted. This latter screw has the greatest effect when the throttle is nearly closed, being, in fact, inoperative when the throttle is full open. If the acceleration is sluggish, a larger pilot or *auxiliary jet* must be fitted. For further information refer to the following notes.

DE-D 4 (Detachable Drift System)
R. R. Matthews Patent (provisionally protected) U.S. Patent applied for.

CARBURETTOR TUNING

There are various causes of unsatisfactory engine operation which may be traced to the carburettor, but often it is blamed needlessly. As a matter of fact it is better not to attempt to alter the maker's settings. The number of combinations and permutations of choke tubes, jets, and auxiliary jets for each size of carburettor is almost limitless, as a simple calculation will soon show. Occasionally a jet may be substituted to advantage for one a size larger or smaller, but outside this it is well to communicate with the maker if there appears to be good ground for suspicion that the setting could be improved.

If the carburettor is warmed up to its normal working temperature, and is not mechanically damaged or choked, it will very rarely be the cause for defective engine operation.

There are certain characteristic defects in engine operation in which carburation plays a part, and it is proposed now to deal with the principal causes and remedies in the following paragraphs.

Choke Tube too Small.—A good acceleration is obtained, but the maximum speed is too low.

Jet too Large.—Under this condition an engine starts up easily from cold. However, the petrol consumption is very great, and long flames, and black vapour come out of the exhaust pipes.

Jet too Small.—On starting from cold the engine runs erratically for a few revolutions, and then either stops or pops back into the carburettor.

Slow-Running Jet.—When an attempt is made to run an engine slowly, similar defects are observed as is the case with the main jet, according to whether the pilot jet is too large or too small.

Heating.—With modern carburettors provision should always be made for heating the induction pipe, either by aid of the engine circulating water, or by means of a portion of the exhaust gases. This is necessitated in order to make up the heat absorbed by the action of vaporising a considerable quantity of petrol through a small jet in a confined space. If this heat is not supplied there is likely to be condensation in the induction pipe. Momentary dripping of the carburettor, just after the engine is stopped, is caused by incomplete evaporation due to insufficient heating. To facilitate the starting up of an engine the radiator may be filled with hot water.

Popping Back in Carburettor.—The most common cause of this defect is a weak mixture. This may be produced by imperfect carburation, *i.e.*, engine cold, jet too small, air-leaks in induction pipes. In any of these instances the mixture is weak, and burns very slowly—consequently a certain amount of combustion is still occurring when the inlet valve opens, thus igniting the incoming

mixture in the pipes. Another, but less frequent cause is the delayed closing of the inlet valve—due to weak springs or sticky guides.

Carburettor Drips.—This may be due to one of several causes—
 (a) *Dirt on the needle seating*, due to a hole in the filter, scale or rust from the petrol tank piping or fittings. This should be cleared out by flushing with petrol. The jet should also be cleaned at the same time. (b) *Needle seat worn*. (c) *Needle imperfect fit* in its upper and lower guides, or bent. Such a needle must be refitted or bent straight, or preferably exchanged for a new one. (d) *Float perforated*. Place the float in hot water to vaporise the petrol and drive it out at the point of entry, which must then be soldered up, taking care not to heat enough to unsolder any other part of the float. (e) *Float chamber out of adjustment*. See that the balance weights are working freely and that they do not touch the cover of the float chamber. (f) *Pressure too high in petrol tank*. Reduce to normal, and if necessary check pressure gauge. (g) *Insufficient heating causes momentary dripping immediately after stopping the engine*. (h) *Excessive flooding* by hand when starting may make the mixture too rich; in this case it may be necessary to open the throttle some way and give a few turns to the engine to clear off the too rich mixture, or else the engine will not start. (i) *External causes*, such as a leaking petrol pipe or union, may account for the dripping, and therefore search should be made for any outside leaks, which might show themselves at the carburettor. (j) *Precautions against fire*. In order that a back-fire or flashback may not give rise to a fire, due to the presence of petrol spill or drips, on an aeroplane, provision should be made for all such wastage to be drained off.

STANDARD AIRCRAFT GAUZE FOR CARBURETTORS AND FUEL FILTERS

	Warp.		Wet.
	100	×	150
Gauge	40		42
Diameter	0.0048 in.		0.0040 in.
Aperture	0.0052 in.	×	0.0027 in.

Apertures per square inch, 15,000.

Aggregate opening per square inch, 0.212 sq. in.

CARBURETTORS

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TYPICAL EXAMPLES OF JET SETTINGS (Zenith Carburettor)

Engine.	Horse-Power.	Cyls.	Bore.	Stroke.	Choke Tube.	Main Jet.	Compensating Jet.
			Mm.	Mm.	Mm.	Mm.	Mm.
Anzani -	105	10	105	145	26	1.40	1.55
Renault -	130	12	96	120	25	1.25	1.10
Salmson -	140	9	120	140	27	1.50	1.40
Hispano-Suiza	150	...	...	...	28	1.40	1.50
Beardmore -	160	6	142	175	30	1.70	1.60
Salmson -	200	9	140	170	32	1.60	1.70
Renault -	200	12	...	...	36	2.00	2.00

All the above engines employ double carburettors

WEIGHT OF CARBURETTORS (Zenith Aircraft)

Type.	Diameter of Outlet.	Weight.	
	Mm.	Lbs.	Oz.
D.E.F. -	42	3	3
D.E.F. -	48	3	10
R.A. -	48	4	2
D.C. -	48	6	5
D.F. -	48	6	3
D.A. -	42	12	8
D.C. -	42	12	8

The above carburettors are made of aluminium with brass fittings.

TYPICAL EXAMPLES OF JET SETTINGS (Zenith Carburettor)

ENGINE.	Choke.	Main.	Compensator.
Beardmore, 160 H.P. -	30	355	335
B.P.H., 200 H.P. -	36	440	470
Hispano-Suiza, 150 H.P. -	28	265	280
Do. 200 H.P. -	42	740	530

Note.—The sizes of the main and compensator jets are given in terms of a flow meter.

COOLING SYSTEM

The air-cooled engine has not made much progress, considering its great possibilities. At the moment the water-cooled engine is the best solution of the problem. Other substitutes for water have been tried, but taking into account the conditions of varying temperature and altitude, nothing has been discovered that will more efficiently replace it. Occasionally a little glycerine or alcohol is mixed with the water to prevent freezing. There are two principal types of radiator construction—(a) with water circulation inside of circular or flat gilled tubes, upon which latter the air can impinge; (b) with water circulation outside of tubes, through which the air passes. These are generally constructed in the form of honeycombs of circular, hexagonal, or square sectional tubes.

The first-mentioned type provides a cooling surface at a small cost in weight, but it is accompanied by a big increase in resistance, and therefore is only suitable for motor car work. Flat tube construction provides a bigger cooling surface per lb. of water contained, but owing to the tangential air flow, the surface is not so effective as with round tubes. Also they require stiffening sideways in some way, which adds to the weight, and reduces the cooling surface. One method of stiffening is to corrugate or zigzag the tubes. This simulates a honeycomb, without the advantage of multiple passages.

Since air is more viscous and has a lower specific heat than water, it should have the freest possible access. This points to the honeycomb type radiator as being preferable.

Again, a cooling surface is more efficient when exposed to the direct normal impact of air than when the air flow is parallel to the surface, hence flat tube type radiators should not be employed.

If a radiator is too compact, the loss of energy due to eddy formation in the rear of the tubular surfaces, and to the baffling effect of flow over successive rows of tubes, causes the head resistance to be high.

Increase in density causes the apparent air velocity to be higher than the true velocity in the ratio of the square roots of the densities. The cooling effect (after due correction) of instrument readings is found to be directly proportional to the density, and consequently the resistance may be said to vary approximately with the temperature. Varying conditions of humidity have no effect on the efficiency of radiators.

As the radiators of modern machines have to be exposed to considerable extremes of temperature, arrangements must be provided

COOLING SYSTEM

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for shielding the radiators when exposed to low temperatures. This is usually accomplished by the aid of shutters or blinds, or alternatively by sliding the radiator itself in or out of the fuselage as required.

Three to five gallons of water are usually required per 100 H.P., or 0.3 to 0.5 lb. per B.H.P. An increased rapidity in the circulation of the cooling water through a radiator greatly increases the efficiency. Radiators usually weigh about three-quarters of a pound per B.H.P. They are often situated on the basis of 0.389 lb. per 1,000 B.Th.U.

CIRCULATION OF RADIATOR WATER ON LIBERTY ENGINE

R.P.M.	Lbs. Press. per Square Inch at Pump.		Gallons per Minute.
	Inlet.	Outlet.	
1,000	1.8	2.5	14.3
1,100	2.2	2.6	15.4
1,200	2.8	2.7	16.1
1,300	3.1	3.0	16.7
1,400	3.3	3.5	17.2
1,500	3.4	4.5	17.5

Effect of Altitude.—Water boils at a lower temperature at high altitudes. The approximate scale being 1 to 1.5° Cent. for every 1,000 ft.

LUBRICATION SYSTEM

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Lubricating Oil.—A temperature of 66° Cent. (150.8° F.) should not be exceeded, or else a good working viscosity will not be maintained. This condition of temperature can only be assured on the dry sump system, where all the oil not actually being pumped under pressure, around the engine bearings, is pumped out of the sump into a storage and cooling tank (open to the atmosphere). The dry sump principle has been proved to be the most satisfactory system for big aircraft engines.

Castor oil is employed very largely for all rotary and most water-cooled engines, as it gives superior results to the best mineral oils. It is practically non-mixable with petrol, and hence is essential for use in rotary engines.

When castor oil is mixed with other oil it tends to lose its viscosity, oxidise, gum and carbonise, and generally get spoiled as a lubricant, unless special precautions are taken to properly blend in suitable proportions. A mixed oil is, however, superior to pure castor oil for resisting the effects of extreme cold. At low temperatures the solid fats or vaselines tend to separate out, when the oil is allowed to stand. All oils should be prepared in such a manner as to resist too much thickening under low temperature conditions.

A good non-freezing oil mixture is 96 per cent. of finest cold drawn winter castor oil (pharmaceutical) blended with about 4 per cent. of a standard refrigerator oil such as Vacuum P 939.

Consumption.—The lubricating oil consumption of a well-designed aircraft engine should not exceed 5 pints per hour, or alternatively 0.05 pint per B.H.P.-hour.

Tests.—The following are two tests, selected at random, of two standard oils suitable for aircraft engines:—

	Vacuum B.B.	Wakefield's Gastrol.
Specific gravity at 15° C. - - -	.8997	.963
Viscosity at 37.8° C. = 100° F. -	800 secs.	1000 secs.
Redwood } 60° C. = 140° F. -	271 "	302 "
in secs. } 93° C. = 200° F. -	86.7 "	89.7 "
} 120° C. = 248° F. -	52 "	53.7 "
Flash point. } ° C. open method -	246° C.	250° C.
Fire test. } -	286° C.	307° C.
Acidity, gms. KOH per 100 gms. oil -	Nil.	.21 gm.
Mineral oil, per cent. - - -	100	10
Setting point, Schultze, ° C. - - -	6.5	...

In cases of mixed oils, the specific gravity of each should be stated. Also the percentage of unsaponifiable matter. Again a test should be made for separation of solid fat, by keeping on ice at 9° Cent. for four to ten days.

Weight.—The average weight of lubricating oil is 9 to 10 lbs. per gallon.

Lubrication of Bearings.—The pressures on bearings are often between 600 lbs. and 2,000 lbs. per sq. in., with a shaft speed of as much as 50 ft. per second. Notwithstanding high pressures and speeds, if oil is fed to that part of the bearing where the load is least, or where the pressures are intermittently reversed, it will be

drawn in and carried round by the shaft. There should not be any oilways in connecting rod big end bearings when forced feed is used. It is generally quite sufficient to make joint chamfer grooves, tapering them off nicely to the bearing surfaces, and not approaching the ends nearer than $\frac{1}{16}$ in. or so. To avoid leaks at end bearings, spiral grooves can be used. Repairers should generally copy the oilways as made by the engine makers. It is as much a mistake to put in too many, as it is to provide them in the wrong place.

The following instructions are given by the Hoyt Metal Company for the lining of high speed internal combustion engine bearings, with a special alloy that they make for the purpose:—

Clean the bearing shell thoroughly, heat it in a clean bunsen flame (which must not reach the surface to be tinned), and tin it with a thin strip of pure tin, or *best quality* solder, using R.A.F. powder flux for preference. After tinning, carefully brush out the shell, and go over it again with the metal and give it a good clean but not too thick coating.

Great care should be taken not to overheat the metal, which must only be hot enough to turn a piece of dry white writing paper light brown, about 575° F. Always have a fair quantity of metal in the pot, as it is then easier to keep the heat steady. Stir frequently, and before ladling out.

When the bearing is ready, heat the jig, bearing, and hollow mandrel with the bunsen flame, or over a gas ring until the tinned surface *nearly runs*, then pour the metal in. If the bearing is too hot or not hot enough, the metal may not stick. When finished, use a cold blast of air or wet cotton waste to cool down—the quicker the better.

If the metal is to be kept hot for any length of time, it should be covered with a thin layer of vegetable charcoal, which may be purchased very cheaply from any chemist or oil and colour merchant.

Connecting rods are sometimes made of special steel, and occasionally the white metal does not hold on as well as might be desired. In such cases, special care must be taken in tinning, which should be done with pure tin for preference. R.A.F. powder flux must always be used for steel.

Blowholes are generally due to the following causes:—White metal too hot or not hot enough; mandrel or inside of bearing damp with oil or water; some of the flux used in tinning has been left in the bearing; air has been trapped in some way; metal has "caved in" owing to leaks; or moisture from the material used to stop leaks has got in.

Common and obvious causes of hot bearings are:—Lubrication unsatisfactory; bad, unsuitable, or dirty oil; bearings out of line or overloaded; shaft bent or whipping; bearings too tight; bearing too long for its diameter; oil has got behind the white metal and prevents escape of heat. The obvious cure in the last instance is to pay careful attention to the tinning of the bearing shell, and the firm adhesion of the white metal to it, in order that whatever heat may exist shall be able to get away into the bearing shell, and thence into and through the parts which carry the bearing.

Those who are interested should obtain copies of "Notes on the Lubrication of the Bearings of Internal Combustion Engines," and "Hints on Lining Bearings," published gratis by the Hoyt Metal Company, 26 Billiter Street, E.C. 3.

621.431.42

Ignition.—This is almost universally attained by the use of a magneto. The modern magneto is a very reliable instrument, and rarely goes wrong. Its only faults are its weak spark when retarded and its small range of advance. It requires no attention, provided it is kept dry and free from oil and dirt. It requires the minimum of lubrication, as it runs on ball bearings. The only maintenance needed is to keep the contact-breaker contacts and the distributing brushes clean. Occasionally, if damp gets in, the fibre brushing of the contact-breaker arm sticks. The contact gap should always be carefully adjusted to about 0.4 mm. (approx. $\frac{1}{16}$ in. or $\frac{1}{4}$ in.), and the surfaces filed so as to make contact all over. As magnetos are so often placed in inconvenient positions, a small key for the removal of the contact-breaker for inspection purposes should be kept handy.

If two magnetos are fitted to an engine, care must be taken to see that they synchronise. A magneto setting is always made with full advance, as this is the normal position of operation when the engine is in use. Magneto advance should normally be from 12 to 15 mm. The break at the contact-breaker, to give the maximum spark, should occur just as the armature shield leaves the pole piece, as this is the moment at which the maximum current is generated by the magneto. Each magneto should have its own earthing switch, so that either may be tested alone with its own set of sparking plugs. Where there are two magnetos, one is usually connected with a hand-starting magneto.

For detailed information concerning high tension ignition for aeroplane engines, the reader is referred to the *Aeronautical Journal* for April-June 1917, which contains a very able paper by Mr A. P. Young.

FIRING ORDER OF CYLINDERS

Four-cylinder vertical (cranks at 180 degrees)	-	-	-	1, 2, 4, 3.
Or alternatively	-	-	-	1, 3, 4, 2.
Six-cylinder vertical	-	-	-	1, 5, 3, 6, 2, 4 (right hand), or 1, 4, 2, 6, 3, 5 (left hand).
Six-cylinder radial, with two cranks at 180 degrees	-	-	-	1, 6, 5, 4, 3, 2.
" " "	-	-	-	1, 5, 3, 0, 2, 4.
" " "	-	-	-	1, 4, 2, 6, 3, 5.
" radial	-	-	-	1, 2, 3, 4, 5, 6.
Seven-cylinder rotary {	-	-	-	1, 3, 5, 7, 2, 4, 6.
Seven-cylinder radial }	-	-	-	
(Firing impulses at equal angular displacements of 120 degrees) (In inverse numerical order.)				
Eight-cylinder, 90 degree Vee	-	-	-	1, 1', 2, 2', 4, 4', 3, 3'.
" " "	-	-	-	1, 1', 3, 3', 4, 4', 2, 2'.
" " "	-	-	-	1, 5, 3, 7, 4, 8, 2, 6.
Nine-cylinder radial	-	-	-	1, 3, 5, 7, 9, 2, 4, 6, 8.
" " rotary	-	-	-	1, 3, 5, 7, 9, 2, 4, 6, 8.
Twelve-cylinder, 60 degree Vee	-	-	-	1, 12, 9, 4, 5, 8, 11, 2, 3, 10, 7, 6.
" " "	-	-	-	1, 6', 4, 3', 2, 5', 6, 1', 3, 4', 5, 2'.

By observing the order in which the inlet valves of an engine open, the sequence of firing of the cylinders can be ascertained.

SPARKING PLUGS

Sparking Plugs of special design are required for different types of engines according to the characteristics of the latter. The problem is less easy of solution, as the efficiency and compression become higher, on account of the greater difficulty in ensuring effective cooling. In the instance of rotary engines, the plug must safely withstand the centrifugal force without any fear of the plug being damaged, or the sparking points bending. Further, it must stand a considerable amount of oil without failing. It is important that it should be as light as possible, so that the centrifugal force caused by the weight of the plug shall not distort the cylinder wall, which is often only of the order of a little over a millimetre or so in thickness. Nuts must be avoided for affixing the high tension leads to the plugs, for such adjustable connections would be liable to fly off, due to centrifugal action.

Triple or annular sparking points are generally preferred for rotary engines. On cylinders that do not revolve, either annular spark gaps or single point gaps are used. The Beardmore engine adopts a three-point gap, and the Gnome an annular gap. The Lodge Sparking Plug Company make the following recommendations :—

Engine.	Spark Gaps.	Type.
Anzani - - - -	Single point	Light weight
Beardmore - - -	Three "	" "
Clérget - - - -	Three "	Extra light weight
Curtiss - - - -	Single "	Light weight
Gnome - - - -	Three "	Extra light weight
Green - - - -	Single "	Light weight
Hispano-Suiza - -	Three "	" "
Le Rhone - - - -	Three "	Extra light weight
R.A.F. - - - -	Single "	Quick cooling
Renault - - - -	" "	" "
Rolls-Royce - - -	Annular "	Light weight
Salmson - - - -	Three "	Extra light weight
Sunbeam-Coatalen -	Single "	Light weight

The standard size plug is the 18 mm. metric. The slightly larger American plug sizes do not seem to be so satisfactory. The distance between the sparking points should be adjusted to about 0.4 mm. (approx. $\frac{1}{16}$ or $\frac{1}{8}$ in.). In use the gap tends to increase, since the metal at the points is slowly burned away. A good plug should withstand a hydraulic test of 300 lbs. per square inch, and an electrical insulation test of 20,000 volts while under an air pressure of 200 lbs. per square inch.

The metal portion of the body is in some cases tinned with fins to assist cooling.

Sparking plugs should always be removed with the aid of a box spanner, rather than an ordinary spanner, as there is less strain on the engine and plug. When the points are coated with oil or carbon, they should be dipped in petrol and cleaned with the aid of a small stiff wire brush. If there are any burns or beads on the electrodes, they should be taken off with a thin magneto file or a knife blade and emery paper, and then cleaned in petrol and adjusted. If the insulation is wet, badly encrusted with carbon, or cracked, it should be discarded for a new one, as it does not pay to run risks with an aero engine.

WEIGHT AND HOURS OF FLIGHT

WEIGHT AND HOURS OF FLIGHT 621.431.75

Engine, Rated H.P.	B.H.P.	Engine Weight.	Weight of Cowling, Mounting Propeller, etc.	Petrol, Oil Tanks, Weight per Hour.	Total Weight for a Flight of Hours.			
					2	4	6	8 10
60-65 Anzani -	65	Lbs. 250	Approx. 60	55	420	530	640	750 860
50-60 Green -	65	400	100	50	600	700	800	900 1,000
80 Gnome -	68	200	90	85	460	630	800	970 1,140
70 Renault -	72	350	74	72	568	712	856	1,000 1,144
80 Le Rhone -	85	240	100	95	530	720	910	1,100 1,290
90 Salmson -	85	450	96	72	690	834	978	1,122 1,266
100 Gnome -	95	280	120	105	610	820	1,030	1,240 1,450
90-100 Green -	110	580	86	82	830	994	1,158	1,322 1,486
120 Austro-Daimler	125	600	110	89	888	1,066	1,244	1,422 1,600

AERO ENGINES

H.P. AND CYLINDER DIMENSIONS

ENGINE.	Rated H.P.	Type.	No. of Cyls.	Bore.		Stroke.		Bore and Stroke Ratio.
				Mm.	In.	Mm.	In.	
Curtiss OX5	90	V-90°	8	101.5	4	127	5	1.25 -1
" VX	160	V-90°	8	127	5	177.8	7	1.41 -1
Liberty 8	270	V-45°	8	127	5	177.8	7	1.40 -1
" 12A	400	V-45°	12	127	5	177.8	7	1.40 -1
Hispano-Suiza	150	V-90°	8	120	4.72	130	5.12	1.08 -1
" "	180	V-90°	8	120	4.72	130	5.12	1.08 -1
" "	300	V-90°	8	140	5.5	150	5.90	1.07 -1
Le Rhone	80	Rotary	9	106	4.13	140	5.51	1.32 -1
Gnome	100	"	9	110	4.33	150	5.90	1.36 -1
ABC Wasp	170	Radial	7	114.3	4.5	130	5.12	1.31 -1
" Dragon-Fly	320	"	9	140	5.5	165	6.5	1.18 -1
BR 1	150	Rotary	9	"	6.72	"	6.06	1.42 -1
BR 2	200	"	9	"	5.51	"	7.08	1.285 -1
Beardmore	180	Vert.	6	142	"	175	"	1.23 -1
Galloway	240	"	6	145	5.71	190	7.48	1.31
Siddeley	240	"	6	"	5.71	"	7.48	1.31
Hispano	150	V-90°	8	"	4.72	"	5.12	1.08 -1
" "	180	V-90°	8	"	4.72	"	5.12	1.08 -1
Rolls-Royce Falcon 3	220	V-60°	12	"	4.90	"	5.75	1.44 -1
" Eagle 8	360	V-60°	12	"	4.5	"	6.5	1.44 -1
Sunbeam Arab	200	V-90°	8	120	4.72	130	5.12	1.08 -1
" Maori	250	V-90°	12	"	5.94	"	5.31	1.35 -1
" Cossack	320	V-60°	12	"	4.33	"	6.30	1.45 -1
Clerget 92	110	Rotary	9	120	4.72	"	6.30	1.33 -1
" 92	130	"	9	"	4.72	"	6.30	1.33 -1
Hispano (French)	180	V-90°	8	"	4.72	"	5.12	1.08 -1
" "	200	V-90°	8	"	4.72	"	5.12	1.08 -1
Lorraine Dietrich	275	V-90°	8	120	4.72	175	6.89	1.46 -1
Fiat A12bis	275-300	Vert.	6	160	6.3	180	"	1.12
" A14	600	"	12	"	6.69	"	8.27	1.235 -1
I.F. V5	200	"	8	130	"	190	"	"
Spa 6A	200	"	6	135	"	170	"	"
Benz	220	Vert.	6	145	"	190	"	"
Maybach	200	"	6	150	"	190	"	"
Mercedes	160	"	6	140	"	160	"	"
"	280	"	6	160	"	180	"	"
Oberursel	110	"	"	"	"	"	"	"

Also refer to following tables.

AERO ENGINES—Continued

R.P.M. AND ORDER OF FIRING

ENGINE.	B. H. P. and R. P. M. at Ground Level.				Com- pression Ratio.	Piston Speed, Ft./ Min.	Order of Firing.
	Normal.		Maximum.				
	B. H. P.	R. P. M.	B. H. P.	R. P. M.			
Curtiss OX5	93	1,400	95	1,450	4.5	1,166	1L, 1R, 2L, 2R, 4L, 4R, 3L, 3R
„ VX	206	1,350	214	1,450	4.71	1,575	1L, 1R, 2L, 2R, 4L, 4R, 3L, 3R
Liberty 8	270	1,700	285	1,850	18 %	1,980	.....
„ 12A	400	1,700	430	1,800	18 %	1,980	1L, 6R, 5L, 2R, 3L, 4R, 6L, 1R, 2L, 5R, 4L, 3R
Hispano-Suiza	150	1,450	170	1,700	4.8 -1	1,240	1L, 4R, 2L, 3R, 4L, 1R, 3L, 2R
„	180	1,700	205	1,800	5.3 -1	1,450	1L, 4R, 2L, 3R, 4L, 1R, 3L, 2R
„	300	1,600	340	1,800	5.3 -1	1,578	1L, 4R, 2L, 3R, 4L, 1R, 3L, 2R
Le Rhone	80	1,200	85	1,300	1.33-1	1,100	1, 3, 5, 7, 9, 2, 4, 6, 8
Gnome	103	1,200	110	1,300	4.0 -1	1,180	1, 3, 5, 7, 9, 2, 4, 6, 8
ABC Wasp	170	1,750	200	1,850	4.025	1,690	1, 3, 5, 7, 2, 4, 6
„ Dragon-Fly	320	1,650	350	1,750	4.025	1,785.5	1, 3, 5, 7, 9, 2, 4, 6, 8
BR 1	154	1,250	156	1,300	5.9 -1	1,394	1, 3, 5, 7, 9, 2, 4, 6, 8
BR 2	238	1,300	242	1,350	5.3 -1	1,475	1, 3, 5, 7, 9, 2, 4, 6, 8
Beardmore	178	1,350	192	1,450	4.56-1	1,435	1, 5, 3, 6, 2, 4
Galloway	236	1,400	250	1,500	4.96-1	1,558	1, 5, 3, 6, 2, 4
Siddeley	240	1,400	250	1,500	5 -1	1,558	1, 5, 3, 6, 2, 4
Hispano	156	1,500	165	1,600	4.8 -1	1,280	1, 4, 2, 3, 4, 1, 3, 2
„	220	2,000	225	2,100	5.3 -1	1,707	1, 4, 2, 3, 4, 1, 3, 2
Rolls-Royce	270	2,200	280	2,300	5.3 -1	2,108	Rht. 1, 2, 5, 4, 3, 1 6, 5, 2, 3, 4, 6
Falcon 3	350	1,800	360	1,900	5.2 -1	1,950	Rht. 1, 2, 5, 4, 3, 1 6, 5, 2, 3, 4, 6
Rolls-Royce	217	2,000	224	2,100	5.3 -1	1,710	1, 1A, 2, 2A, 4, 4A, 3, 3A
Eagle 8	265	2,100	280	2,200	5.6 -1	..	1, 5, 3, 6, 2, 4
Sunbeam Arab	350	2,000	384	2,100	5 -1	2,100	1, 5, 3, 6, 2, 4
„ Maori	122	1,250	123	1,300	4.36-1	1,200	1, 3, 5, 7, 9, 2, 4, 6, 8
„ Cossack	127	1,250	..	..	4.56-1	1,312	1, 3, 5, 7, 9, 2, 4, 6, 8
Clerget 92	208	2,000	225	2,100	5.3 -1	1,707	1, 4, 2, 3, 4, 1, 3, 2
„ 92	220	2,000	215	2,100	4.81	1,707	1, 4, 2, 3, 4, 1, 3, 2
Hispano (French)	278	1,650	..	..	..	..	.....
Lorraine Dietrich	304-290	1,600	325	1,700	4.31-1	1,653	1, 5, 3, 6, 2, 4
Fiat A12bis	700	1,500	725	1,600	..	..	.....
„ A14	250	1,400	268	1,600	5	1,995	.....
I. F. V5	210	1,600	225	1,700	5	1,895	.....
Spa 6A	230	1,400	252	1,650	4.93	1,745	.....
Benz	200	1,200	..	..	..	1,496	.....
Maybach	150	1,250	..	..	4.8-4.52	1,312	.....
Mercedes	252	1,400	260	1,500	4.94	1,635 at	.....
„	..	..	..	..	..	1,400	.....
Oberursel	..	..	..	..	..	..	.....

Also refer to preceding and following tables

AERO ENGINES—Continued

M.E.P. AND VALVES

ENGINE.	Method of Cooling.	M.E.P. lbs. per Sq. In.	Valves per Cylinder.							
			Inlet.				Exhaust.			
			No.	Dia., In.	Total Area, Sq. In.	Lift, In.	No.	Dia., In.	Total Area, Sq. Cm.	Lift, In.
Curtiss OX5 . . .	W	111	1	1.0094	2.0023	.3437	1	1.0094	2.3267	.3878
" VX . . .	W	110	1	2.7559	3.2306	.3740	1	2.7559	3.2306	.3740
Liberty 8 . . .	W	115	1	2.5	3.4344	.4375	1	2.5	2.9437	.3750
" 12A . . .	W	115	1	2.5	3.4344	.4375	1	2.5	2.9437	.3750
Hispano-Suiza . .	W	114	1	1.9085	2.4350	.3937	1	1.9085	2.4350	.3937
" " . . .	W	122	1	1.9085	2.9350	.3937	1	1.9085	2.4350	.3937
" " . . .	W	125	1	1.5629	1.7313	.3593	1	1.5629	1.4492	.2952
Le Rhone . . .	A	81	1	1.5629	1.7313	.3593	1	1.5629	1.4492	.2952
Gnome . . .	A	88 7	0	1.5629	1.7313	.3593	1	1.5629	1.4492	.2952
ABC Wasp . . .	A	115	1	2.17	3.33	.4700	2	1.338	2.4800	.2950
" Dragon-Fly . .	A	114	1	2.6559	5.4537	.6535	2	1.6929	2.2992	.4330
BR 1 . . .	A	94	1	1.77	2.41	.4300	1	2.00	2.7300	.4300
BR 2 . . .	A	95.2	1	2.47	3.9554	.5100	1	2.28	3.0510	.5100
Beardmore . . .	W	103	1	2.559	4.0455	.4724	2	1.8110	4.2346	.4724
Galloway . . .	W	116	1	2.7165	3.9060	.4724	2	1.7322	5.2080	.4724
Siddeley . . .	W	118.1	1	2.5984	3.9060	.4724	2	1.7322	5.2080	.4724
Hispano . . .	W	114.75	1	1.9085	2.4350	.3937	1	1.9085	2.4350	.3900
" " . . .	W	121.8	1	1.9085	2.4350	.3937	1	1.9085	2.4350	.3937
Rolls-Royce . . .	W	114	1	1.7496	2.4211	.4437	1	1.7496	2.4211	.4400
Falcon 3 . . .	W	124	1	2.0000	2.9155	.4850	1	2.0000	2.9155	.4800
Rolls-Royce . . .	W	124	1	2.0000	2.9155	.4850	1	2.0000	2.9155	.4800
Eagle 8 . . .	W	115	1	2.126	2.3631	.3543	2	1.2598	2.3088	.3543
Sunbeam Arab . .	W	125	2	1.6142	3.0952	.3543	2	1.6142	1.8476	.3500
" Maori . . .	W	121	2	1.6142	3.0952	.3543	2	1.6142	1.8476	.3500
" Cossack . . .	W	121	2	1.6142	3.0952	.3543	2	1.6142	1.8476	.3500
Clerget 92 . . .	A	78	1	1.5748	1.9423	.3937	1	1.9085	2.3031	.4528
" 92 . . .	A	81	1	1.692	2.24	.3900	1	1.9085	3.038	.4527
Hispano (French) .	W	121.8	1	1.9085	2.4350	.3900	1	1.9085	2.4350	.3931
" " . . .	W	115	1	1.9085	2.4350	.3900	1	1.9085	2.4350	.3937
Lorraine Dietrich .	W	105	2	2.00	5.5180	.4300	2	2.0078	5.518	.4375
Fiat A12bis . . .	W	108	2	2.00	5.5180	.4300	2	2.0078	5.518	.4375
" A14 . . .	W	107.6	2	2.00	5.5180	.4300	2	2.0078	5.518	.4375
I.F. V5 . . .	W	107.6	2	2.00	5.5180	.4300	2	2.0078	5.518	.4375
Spa 6A . . .	W	116.6	2	2.00	5.5180	.4300	2	2.0078	5.518	.4375
Benz . . .	W	113	2	2.244	3.8998	.4300	2	2.244	3.8998	.4300
Maybach . . .	W	107.4	2	2.244	3.8998	.4300	2	2.244	3.8998	.4300
Mercedes . . .	W	105.2	2	2.244	3.8998	.4300	2	2.244	3.8998	.4300
" " . . .	W	107.5	2	2.244	3.8998	.4300	2	2.244	3.8998	.4300
Oberursel . . .	W	107.5	2	2.244	3.8998	.4300	2	2.244	3.8998	.4300

Also refer to preceding and following tables.

AERO ENGINES—Continued

CARBURETTORS AND MAGNETOS

ENGINE.	Carburettor.			Magneto.		
	No.	Type.	Weight Each, Lbs.	No.	Type.	Speed × E.S. Weight Each, Lbs.
Curtiss OX5	1	Zenith Duplex	4.2	1	Berling	2 21
" VX	2	" "	"	1	"	2 ..
Liberty 8	1	" "	7	1	Twin Delco Generator, 8-volt	1.5 ..
" 12V	2	Zenith Duplex U.S. 52	"	1	Twin Delco Generator, 8-volt	1.5 ..
Hispano-Suiza	1	Zenith Duplex 48 D.C.	7.0	2	8-Cyl. Dixie Transverse	2 ..
" "	1	Zenith Duplex 58 D.C.	9.5	2	8-Cyl. Dixie Transverse	2 ..
" "	1	" "	9.5	2	8-Cyl. Dixie Transverse	2 ..
Le Rhone	1	Mixing Valve	4.10	1	A.D.S. 26' Early	9/4 9.10
Gnome	1	"	"	1	"	6/4 ..
ABC Wasp	2	A.B.C. Injectors	"	2	P.L.7 M.L.P.	1.75 ..
ABC Dragon-Fly	2	H.C. 8	"	2	M.L.9	1.18 13.5
BR 1	1	Block Tube	5	2	A.D.S. M.L.	2.25 10
BR 2	1	"	"	2	M.L.	" 10
Beardmore	2	Zenith	5.75	2	D.U. 68.	1.5 16
Galloway	2	48 Zenith RA	3.25	2	E.M.6	1.5 15
Siddeley	2	Zenith	4.2	2	E.M.6	1.5 15
Hispano	1	Zenith Duplex 48 D.C.	7.0	2	1A8S	E.S. 17.75
"	1	Zenith Duplex 58 D.C.	9.5	2	1A8S. 1AB	E.S. 18.12
"	1	R.R.C.H. 38 M.	"	2	Watford	1.5 14.25
Rolls-Royce Falcon 3	2	R.R.C.H. Duplex 42 m/m.	13.000	4	"	1.5 14.25
Rolls-Royce Eagle 8	1	C.H.H.C.7	"	2	B.T.H. A8S	E.S. 12.8
Sunbeam Arab	4	C.H.B.Z.S. 42 m/m.	"	4	W.B.G.	1.5 19.1
" Maori	4	C.H.B.Z.S. 42 m/m.	"	4	B6 or W.B.G.	1.5 19.1
" Cossack	4	C.H.B.Z.S. 42 m/m.	"	4	"	"
Clerget 92	1	Block Tube Bush D.A.L.	4.41	2	A.D.S.	E.S. 9.10
" 92	1	Block Tube	5.0	2	"	2.25 9.10
Hispano (French)	1	Zenith Duplex 58 D.C.	9.5	2	1A8S. 1AB	E.S. 18.12
"	1	" "	9.5	2	S.E.V.	E.S. 17.75
"	1	" "	"	2	"	16.3
Lorraine Dietrich	1	Siemens	"	2	6-Cyl. Dixie 60-V.	1.5 ..
Fiat A12bis	1	"	"	2	"	" ..
" A14	1	"	"	2	"	" ..
I.F. A5	1	"	"	2	"	" ..
Spa 6A	1	"	"	2	"	" ..
Benz	1	"	"	2	2 H 6 Bosch	" ..
Maybach	2	Maybach	"	2	"	" ..
Mercedes	2	Duplex	"	2	"	" ..
"	2	Mercedes	"	2	Bosch	" ..
Oberthurst	1	"	"	2	"	" ..

Also refer to preceding and following tables.

AERO ENGINES—Continued

PUMPS

ENGINE.	Oil Pump.			Water Pump.			Air Pump.		
	No.	Type.	Weight Lbs.	No.	Type.	Weight Lbs.	No.	Type.	Weight Lbs.
Curtiss OX5	1	Gear	..	1	Centrif.	..	..	Nil	..
" VX	3	"	..	1	"	..	..	"	..
Liberty 8	3	"	..	1	"	..	1	Plunger	..
" 12A	3	"	..	1	"	..	1	"	..
Hispano-Suiza	1	Eccentric	..	1	"	..	1	"	..
" "	1	Vane Type	..	1	"	..	1	"	..
" "	1	Eccentric	..	1	"	..	1	"	..
" "	1	Vane Type	..	1	"	..	1	"	..
Le Rhone	1	Gear	..	1	"	..	1	"	..
" "	1	Plunger	4'125	..	..	..	..	..	..
Gnome	1	Two Plunger	..	..	..	..	..	..	..
ABC Wasp	1	Gear	..	..	..	..	..	..	..
ABC Dragon-Fly	1	Plunger Dis-	..	..	..	..	..	..	..
"	1	tributed	..	..	..	..	..	..	..
BR 1	1	Plunger	6'63	..	Nil	..	1	Plunger	4'7
BR 2	1	"	6'63	..	"	..	1	"	..
Beardmore	1	"	..	1	Centrif.	4'9	..	"	..
Galloway	1	Rotary	4'96	1	"	6'51	1	Plunger	8'8
Siddeley	2	Gear	4'1	1	"	7'2	1	"	7
Hispano	1	Eccentric	..	1	"	2'69	1	"	15 oz.
"	2	Vane	..	1	"	2'60	..	"	..
"	2	Eccentric	..	1	"	2'60	..	"	..
Rolls-Royce Falcon	3	Rotary	..	1	"	..	2	"	2'75
" Eagle 8	2	Gear	8'75	1	"	4'625	1	"	2'875
Sunbeam Arab	3	"	..	1	"	3	1	"	..
" Maori	3	"	..	1	"	..	1	"	..
" Cossack	3	"	..	1	"	..	1	"	..
Clerget 92	1	"	6'63	..	..	..	1	"	4'8
" 92	1	Plunger	6'63	..	Nil	..	1	"	4'7
Hispano (French)	2	Eccentric	..	1	Centrif.	2'69	1	"	15 oz.
"	2	Vane	..	1	"	..	1	"	..
"	1	Eccentric	..	1	"	..	1	"	13 oz.
"	1	Vane	..	1	"	..	1	"	..
Lorraine Dietrich	..	..	..	..	..	..	..	..	..
Fiat A12bis	3	Gear	..	1	Centrif.	..	1	Plunger	..
" A14	..	..	..	1	"	..	..	..	..
I.F. V5	..	..	..	..	..	..	..	..	..
Spa 6A	..	..	..	..	..	..	..	..	..
Benz	..	Gear	..	..	Centrif.	..	..	..	..
Maybach	1	Plunger	..	..	Axial Tur.	..	..	..	..
Mercedes	2	..	..	..	..	..	..	..	..
"	..	Mercedes	..	..	Axial Tur.	..	..	..	..
"	..	4-Plunger	..	..	..	..	..	..	..
Oberursel	..	..	..	..	..	..	..	..	..

Also refer to preceding and following tables

AERO ENGINES—Continued

GEARS AND OVERALL DIMENSIONS

ENGINE.	Ratio of Gear Reduc-tiop.	Speed of Propeller.	Tractor or Pusher.	Overall Dimensions.		
				Length, Mm.	Width, Mm.	Height, Mm.
Curtiss OX5	Nil	E.S.	Either	1,408	753	841
" VX	"	"	"	.....	.....	.....
Liberty 8	"	"	Either	.....	.....	1,020
" 12A	"	"	"	1,755	.....	1,020
Hispano-Suiza	"	"	"	1,308	851	832
"	"	"	"	1,388	851	832
Le Rhone	"	"	"	.....	.....	.....
Gnome	"	"	"	.....	.....	.....
ABC Wasp	"	"	T.	35.7"	42.20"	42.20"
" Dragon-Fly	"	"	T.	1,070	1,232	1,207
BR 1	Nil	"	Either	43.5"	47.50"	41.57"
BR 2	"	"	"	.....	.....	.....
Beardmore	"	"	"	57.08"	19.92"	31.88"
Galloway	"	"	"	67.32"	20.07"	42.91"
Siddeley	"	"	"	69.88"	24.09"	43.62"
Hispano	"	E.S.	"	51.53"	33.46"	32.67"
"	"	"	"	47.24"	33.46"	33.34"
Rolls-Royce	59-1	1,300 r.p.m.	"	72.04"	37.24"	42.00"
Falcon 3	"	"	"	.....	.....	.....
Rolls-Royce	6-1	1,080	"	75.98"	42.52"	48.03"
Eagle 8	"	"	"	.....	.....	.....
Sunbeam Arab	45-27	1,200	T.	1,105	810	903
" Maori	2-1	$\frac{1}{2}$ E.S.	Either	55.11"	35.46	33.85
" Cossack	2-1	"	"	61.81"	37.79	33.89
Clerget 92	"	E.S.	"	36.22"	40.15"	40.15"
" 92	Nil	"	"	36.22"	40.15"	40.15"
Hispano (French)	"	"	"	47.24"	33.46"	33.34"
"	24 x 41 or	1,170 or	"	51.18"	33.46"	33.26"
"	21 x 28	1,500	"	.....	.....	.....
Lorraine Dietrich	"	"	"	.....	.....	.....
Fiat A12bis	Nil	E.S.	Either	.....	.....	.....
" A14	"	"	"	.....	.....	.....
I.P. V5	"	1,400	Either	.....	.....	.....
Spa 6A	"	1,600	"	.....	.....	.....
Benz	"	"	"	.....	.....	.....
Maybach	"	"	"	.....	.....	.....
Mercedes	"	"	"	.....	.....	.....
"	"	"	"			
Oberursel	"	"	"	.....	.....	.....

Also refer to preceding and following tables.

FUEL AND OIL DATA

[illegible]

206

Dr. D-4 (Detachable Data) System
R. Barker Matthew, Patents provisionally protected. U.S. Patent applied for

AERO ENGINE DATA

621.431.75

AERO ENGINES—Continued

WEIGHTS

ENGINE.	Total Fuel and Oil per Hour.		Weight of Engine Dry.		Weight of Engine in Running Order, less Fuel, Oil, and Tanks.		Weight of Engine with Fuel, Oil, and Tanks for 6 Hours' Running.		Torque in Lbs. Ft.
	Pts. (U.S.)	Lbs.	Lbs.	Lbs. B. H. P.	Lbs.	Lbs. B. H. P.	Lbs.	Lbs. B. H. P.	
Curtiss OX5 . . .	48'06	44'16	385	4'2	445	4'8	6,765	7'3	371
" VX . . .	..	..	..	..	..	..	..	..	..
Liberty 8 . . .	182'24	182'2	575	2'12	..	..	..	..	..
" 12A . . .	192'8	192'8	845	2'11	1,151'5	2'88	..	..	..
Hispano-Suiza . . .	..	85'5	440	2'03	..	..	..	..	..
" " . . .	..	127'2	485	2'69	..	..	..	..	..
" " . . .	..	..	506	1'98	..	..	..	..	..
Le Rhone " . . .	..	..	245	3'05	..	..	..	..	..
Gnome . . .	..	..	270	2'7	..	..	..	..	..
ABC Wasp . . .	94'8	85	260	1'53	260	1'53	820	4'82	510
ABC Dragon-Fly . . .	..	191'5	600	1'88	600	1'88	..	..	1,019
BR 1 . . .	118'2	109'75	405	2'6	405	2'6	1,129'35	7'8	655
BR 2 . . .	176'2	162	475	2	475	2	1,544	6'5	961
Beardmore . . .	108'5	98'96	592	3'3	712	4	1,366	7'6	602
Galloway . . .	143'2	130'45	690	2'95	843	3'57	1,704	7'2	885
Siddeley . . .	147'6	135'85	625	2'6	781	3'25	1,677'6	7'0	900
Hispano . . .	96'5	88'2	455	2'9	657'4	4'20	1,230'5	7'9	546
" " . . .	138'6	127'8	510	2'32	653	2'97	1,492	6'67	583
Rolls-Royce Falcon 3 . . .	161'15	146'6	723	2'68	912	3'38	1,880	6'9	604
" Eagle 8 . . .	204'7	186'2	933	2'66	1,177	3'37	2,406	6'9	1,020
Sunbeam Arab . . .	116'3	106'46	550	2'5	686	3'16	1,380	6'4	570
" Maori . . .	161'2	141'97	890	3'3	1,065	3'95	2,002	7'8	662
" Cossack . . .	208	180'9	1,118	3'2	1,345	3'8	2,598	7'4	919
Clerget 92 . . .	97'5	91'35	307	3	307	3	970	8	512
" 92 . . .	99'05	92'26	400	3'15	400	3'15	1,000	8	533
Hispano (French) . . .	138'6	127'8	510	2'32	653	2'97	1,492	6'67	583
" " . . .	137'8	126'9	503	2'42	638	3'1	1,475'6	7'8	546
Lorraine Dietrich . . .	..	..	..	..	..	..	..	..	..
Fiat A12bis . . .	162'8	147'6	928	3'32	1,110	3'96	2,084	7'44	929
" A14 . . .	366'7	363'7	1,565	2'36	2,020	2'9	4,420	6'3	2,450
I.F. V5 . . .	..	..	825	3'95	..	..	..	..	..
Spa 6A . . .	..	..	539	3'21	..	..	..	..	..
Benz . . .	..	..	829	3'68	..	..	..	..	..
Maybach . . .	..	..	..	..	..	..	..	..	..
Mercedes . . .	..	..	618	3'86	..	..	..	..	..
" " . . .	..	..	935	3'75	..	..	..	..	..
Oberursel . . .	..	..	..	..	..	..	..	..	..

One pint (U.S.) = one pint Imperial measure.
Also refer to preceding and following tables.

AERO ENGINES—Continued**B.H.P. AND FUEL AT VARIOUS ALTITUDES**

ENGINE.	Estimated B.H.P. at				Estimated Fuel Consumption. Pints (U.S.) per Hour Ground Level Carburettor Adjustments. No Altitude Control.			
	6,000 Ft.	10,000 Ft.	15,000 Ft.	20,000 Ft.	6,000 Ft.	10,000 Ft.	15,000 Ft.	20,000 Ft.
Curtiss OX5 . . .	76	67.3	57.5	49.4	42.6	40.1	37.1	34.4
" VX . . .	..	..	..	..	..	..	..	..
Liberty 8 . . .	260	181	148	116	112	100	87	75
" 12A . . .	320	272	220	172	163	144	125	108
Hispano-Suiza . . .	..	..	..	..	..	..	..	..
" " . . .	..	..	..	..	..	..	..	..
Le Rhone . . .	..	..	..	..	..	..	..	..
Gnome . . .	..	..	..	..	..	..	..	..
ABC Wasp . . .	138.11	122.24	104.37	89.07	83.53	78.56	72.68	67.34
" Dragon-Fly . . .	256	218	176	138	149	134	116	100
BR 1 . . .	129	114.2	97.5	83.7	93.7	88.1	81.5	75.5
BR 2 . . .	196.8	174.2	148.75	127.8	146.2	137.5	127.2	117.8
Beardmore . . .	147.2	130.3	111.25	95.0	93.7	88.1	81.5	75.5
Galloway . . .	195.2	172.75	147.5	126.7	124.2	116.8	108	100.1
Siddeley . . .	198.5	175.7	150	129	122	114.7	106.2	98.4
Hispano . . .	129	114.2	97.5	83.8	82.2	77.3	71.5	66.25
" " . . .	182	161	137.5	118	115.8	109	100.8	93.5
Rolls-Royce . . .	227.4	201.3	171.8	147.6	139.8	131.5	121.6	112.7
" Falcon 3 . . .	..	..	..	..	..	..	..	..
Rolls-Royce Eagle 8 . . .	280.5	256.2	218.75	188	178	167.4	154.8	143.5
Sunbeam Arab . . .	179.5	158.8	135.6	116.5	98.5	92.6	85.7	79.4
" Maori . . .	219	194	165.6	142.3	136.2	128.1	118.5	109.8
" Cossack . . .	289.5	256.2	218.75	188	178	167.4	154.8	143.5
Clerget 92 . . .	101	89.3	76.25	65.5	74	69.6	64.4	59.6
" 92 . . .	105	93	79.4	68.2	77.3	72.7	67.3	62.3
Hispano (French) . . .	182	161	137.5	118	115.8	109.0	100.8	93.5
" " . . .	172	152.25	130	111.7	113.3	106.6	98.6	91.3
Lorraine Dietrich . . .	..	..	..	..	..	..	..	..
Fiat A12bis . . .	215	190.3	162.5	139.6	141.6	133.2	123.2	114.2
" A14 . . .	580	512.4	430.75	370.6	306.2	313.7	290.25	268.9
I.F. V5 . . .	..	..	..	..	..	..	..	..
Spa 6A . . .	..	..	..	..	..	..	..	..
Benz . . .	..	..	..	..	..	..	..	..
Maybach . . .	..	..	..	..	..	..	..	..
Mercedes . . .	..	..	..	..	..	..	..	..
" " . . .	..	..	..	..	..	..	..	..
Oberursel . . .	..	..	..	..	..	..	..	..

One pint (U.S.)=one pint Imperial measure.

Also refer to preceding tables.

STANDARD LIMITS

621.715

THE NEWALL STANDARD TABLES OF LIMITS (For Sizes up to 6 in.)

Class.	Nominal Diameters.	Up to $\frac{1}{8}$ ".	$\frac{9}{16}$ "-1".	1 $\frac{1}{8}$ "-2".	2 $\frac{1}{8}$ "-3".	3 $\frac{1}{8}$ "-4".	4 $\frac{1}{8}$ "-5".	5 $\frac{1}{8}$ "-6".
Tolerances in Standard holes, Class A	High limit	+ .0025	+ .0050	+ .0075	+ .0100	+ .0150	+ .0100	+ .0150
	Low "	- .0025	- .0025	- .0025	- .0050	- .0050	- .0050	- .0050
	Tolerance	.0050	.0075	.0100	.0150	.0150	.0150	.0200
Tolerances in Standard holes, Class B	High limit	+ .0050	+ .0075	+ .0100	+ .0125	+ .0150	+ .0175	+ .0200
	Low "	- .0050	- .0050	- .0050	- .0075	- .0075	- .0075	- .0100
	Tolerance	.0100	.0125	.0150	.0200	.0225	.0250	.0300
Allowances on Shafts. Force fits, Class F	High limit	+ .0100	+ .0200	+ .0400	+ .0600	+ .0800	+ .1000	+ .1200
	Low "	- .0050	- .0150	- .0300	- .0450	- .0600	- .0800	- .1000
	Tolerance	.0050	.0050	.0100	.0150	.0200	.0200	.0200
Driving fits, Class D	High limit	+ .0050	+ .0100	+ .0150	+ .0250	+ .0300	+ .0350	+ .0400
	Low "	- .0025	- .0075	- .0100	- .0150	- .0200	- .0250	- .0300
	Tolerance	.0025	.0025	.0050	.0100	.0100	.0100	.0100
Push fits, Class P	High limit	- .0025	- .0050	- .0100	- .0150	- .0150	- .0200	- .0200
	Low "	- .0075	- .0100	- .0150	- .0200	- .0200	- .0250	- .0250
	Tolerance	.0050	.0050	.0050	.0050	.0050	.0050	.0050
Running fits, Class X	High limit	- .0100	- .0125	- .0175	- .0200	- .0250	- .0300	- .0350
	Low "	- .0200	- .0275	- .0350	- .0425	- .0500	- .0575	- .0650
	Tolerance	.0100	.0150	.0175	.0225	.0250	.0275	.0300
Running fits, Class Y	High limit	- .0075	- .0100	- .0125	- .0150	- .0200	- .0225	- .0250
	Low "	- .0125	- .0200	- .0250	- .0300	- .0350	- .0400	- .0450
	Tolerance	.0050	.0100	.0125	.0150	.0150	.0175	.0200
Running fits, Class Z	High limit	- .0050	- .0075	- .0075	- .0100	- .0100	- .0125	- .0125
	Low "	- .0075	- .0125	- .0150	- .0200	- .0225	- .0250	- .0275
	Tolerance	.0025	.0050	.0075	.0100	.0125	.0125	.0150

Allowances for the class of fit required should be made on the shaft. It is preferable to put the actual limits on the drawings, as it saves reference to tables.

THE NEWALL STANDARD TABLES OF LIMITS (For Sizes up to 150 mm.)

Class.	Nominal Diameters.	Up to 15.	16-25.	26-50.	51-75.	76-100.	101-125.	126-150.
<i>Tolerances in Standard holes, Class A</i>	High limit	+ .007	+ .013	+ .019	+ .026	+ .026	+ .026	+ .039
	Low " Tolerance	- .007 - .014	- .007 - .020	- .007 - .026	- .013 - .039	- .013 - .039	- .013 - .039	- .013 - .052
<i>Tolerances in Standard holes, Class B</i>	High limit	+ .013	+ .019	+ .026	+ .032	+ .039	+ .045	+ .051
	Low " Tolerance	- .013 - .026	- .013 - .032	- .013 - .039	- .019 - .051	- .019 - .058	- .019 - .064	- .026 - .077
<i>Allowances on Shafts. Force fits, Class F</i>	High limit	+ .026	+ .051	+ .102	+ .153	+ .204	+ .255	+ .306
	Low " Tolerance	+ .013 - .013	+ .038 - .013	+ .077 - .025	+ .115 - .038	+ .152 - .052	+ .203 - .052	+ .254 - .052
<i>Driving fits, Class D</i>	High limit	+ .013	+ .026	+ .039	+ .064	+ .077	+ .089	+ .102
	Low " Tolerance	+ .007 - .006	+ .019 - .007	+ .026 - .013	+ .039 - .025	+ .051 - .026	+ .063 - .026	+ .076 - .026
<i>Push fits, Class P</i>	High limit	- .006	- .006	- .006	- .012	- .012	- .012	- .012
	Low " Tolerance	- .019 - .013	- .019 - .013	- .019 - .013	- .026 - .014	- .026 - .014	- .026 - .014	- .026 - .014
<i>Running fits, Class X</i>	High limit	- .025	- .032	- .045	- .051	- .063	- .076	- .089
	Low " Tolerance	- .051 - .026	- .070 - .038	- .090 - .045	- .127 - .057	- .146 - .064	- .165 - .070	- .189 - .076
<i>Running fits, Class Y</i>	High limit	- .019	- .025	- .032	- .038	- .051	- .057	- .063
	Low " Tolerance	- .032 - .013	- .051 - .026	- .064 - .032	- .076 - .038	- .089 - .038	- .101 - .044	- .114 - .051
<i>Running fits, Class Z</i>	High limit	- .012	- .019	- .019	- .025	- .025	- .032	- .032
	Low " Tolerance	- .019 - .007	- .032 - .013	- .039 - .020	- .051 - .026	- .057 - .032	- .064 - .032	- .070 - .038

Tolerance is the margin providing for reasonable error in workmanship. Allowance is the necessary difference in the sizes of two pieces that have to go together. The term limits includes both tolerance and allowance

D-E-D-A (Detachable Data) System
R. Borlase Matthews' Patents (provisionally protected). U.S. Patents applied for.

SCREW THREADS

621.881

STANDARD SCREW THREADS

(Used in Aircraft Construction)

Standard.			Threads per Inch.	Full Diameter.			Core Diam.	Area at Bottom of Thread.
Whit- worth.	British Associa- tion.	Inter- national (Metric).						
$\frac{1}{16}$	...	...	60	In. $\frac{1}{16}$	In. .0625	Mm. 1.587	In. .0412	Sq. In. .00133
...	10	...	72.6	$\frac{1}{16} +$	.0670	1.702	.0504	.00199
...	9	...	65.1	$\frac{5}{16}$	.0750	1.905	.0565	.0025
$\frac{5}{16}$	...	...	56	$\frac{5}{16}$	.0781	1.984	.0553	.0024
...	8	...	59.1	$\frac{3}{8}$	.0870	2.209	.0657	.00339
$\frac{3}{8}$	...	...	48	$\frac{3}{8}$	.0937	2.379	.0671	.00353
...	7	...	52.9	$\frac{3}{8} +$	.0980	2.489	.0753	.00445
$\frac{7}{16}$	...	...	48	$\frac{7}{16}$	.1094	2.778	.0827	.00537
...	6	...	47.9	$\frac{7}{16}$	.1100	2.794	.0849	.00566
...	...	3	46.19	$\frac{1}{2}$	.1181	3	.0899	.00634
$\frac{1}{2}$	...	...	40	$\frac{1}{2}$	.1250	3.175	.0930	.00679
...	5	...	43	$\frac{1}{2} +$	.1260	3.2	.0981	.00755
...	...	3.5	46.19	$\frac{9}{16}$	.1378	3.5	.1097	.00945
$\frac{9}{16}$	...	...	40	$\frac{9}{16}$	.1406	3.571	.1086	.00926
...	4	...	38.5	$\frac{9}{16} +$	.1420	3.606	.1108	.00964
$\frac{5}{8}$	...	...	32	$\frac{5}{8}$	.1562	3.967	.1162	.0106
...	...	4	36.28	$\frac{5}{8}$	.1575	4	.1217	.01163
...	3	...	34.8	$\frac{5}{8} +$	.1610	4.089	.1266	.01258
$\frac{11}{16}$	...	...	32	$\frac{11}{16}$	.1719	4.365	.1319	.01366
...	...	4.5	36.28	$\frac{11}{16} +$	.1772	4.5	.1414	.01574
...	2	...	31.4	$\frac{3}{4}$	.1850	4.699	.1467	.0169
$\frac{3}{4}$	...	...	24	$\frac{3}{4}$	.1875	4.762	.1342	.01414
...	...	5	29.88	$\frac{1}{2} -$	.1968	5	.1534	.01848
$\frac{11}{8}$	...	...	24	$\frac{11}{8}$	.2031	5.159	.1498	.01762
...	1	...	28.2	$\frac{1}{2} +$	.2090	5.308	.1665	.02177
$\frac{7}{8}$	...	...	24	$\frac{7}{8}$	.2187	5.555	.1654	.02148
$\frac{15}{16}$	...	...	24	$\frac{15}{16}$	.2344	5.953	.1811	.02576
...	0	...	25.4	$\frac{15}{16} +$	.2360	5.994	.1887	.02796
...	...	6	24.4	$\frac{15}{16} +$	.2362	6	.1859	.02714

STANDARD SCREW THREADS—Continued

Standard.			Threads per Inch.	Full Diameter.			Core Diam.	Area at Bottom of Thread.
Whit- worth.	British Stand- ard, Fine.	Inter- national (Metric).		In.	In.	Mm.		
$\frac{1}{4}$	...	...	20	$\frac{1}{4}$	.25	6.349	.1860	.02717
...	$\frac{1}{4}$	...	26	$\frac{1}{4}$	.25	6.349	.2007	.03163
$\frac{1}{2}$	...	...	20	$\frac{1}{2}$	.265	6.747	.2016	.03192
...	...	7	25.4	$\frac{9}{32}$ -	.275	7	.2244	.03954
$\frac{9}{32}$	...	...	20	$\frac{9}{32}$	.281	7.143	.2172	.03705
...	$\frac{9}{32}$	...	26	$\frac{9}{32}$	.281	7.143	.2320	.04227
$\frac{5}{16}$	...	...	18	$\frac{5}{16}$	.312	7.937	.2414	.04598
...	$\frac{5}{16}$	...	22	$\frac{5}{16}$	.312	7.937	.2543	.05079
...	...	8	20.32	$\frac{1}{4}$ +	.315	8	.2510	.04948
...	...	9	20.32	$\frac{1}{2}$ -	.354	9	.2904	.066235
$\frac{3}{8}$	...	...	16	$\frac{3}{8}$	.375	9.524	.2950	.06835
...	$\frac{3}{8}$	...	20	$\frac{3}{8}$	.375	9.524	.3110	.07596
...	...	10	16.94	$\frac{1}{2}$ +	.393	10	.3170	.07892
...	...	11	16.94	$\frac{7}{16}$ -	.433	11	.3563	.09970
$\frac{7}{16}$	...	...	14	$\frac{7}{16}$	.437	11.112	.3460	.09402
...	$\frac{7}{16}$	...	18	$\frac{7}{16}$	.437	11.112	.3664	.10543
...	...	12	14.51	$\frac{1}{2}$ +	.472	12	.3829	.11515
$\frac{1}{2}$	...	...	12	$\frac{1}{2}$	.5	12.699	.3933	.12149
...	$\frac{1}{2}$	...	16	$\frac{1}{2}$	.5	12.699	.4200	.13854

DE-DA (Detachable Data) System
 R. Borlase Matthews' Patents (provisionally protected). U.S. Patents applied for.

BRITISH STANDARD PIPE THREADS

Nominal Bore of Pipe.	External Diameter.	Threads per Inch.
In.	In.	
$\frac{1}{8}$	.383	28
$\frac{1}{4}$	.518	19
$\frac{3}{8}$	.656	19
$\frac{1}{2}$	.825	14
$\frac{3}{4}$	.902	14
$\frac{7}{8}$	1.041	14
1	1.189	14
1 $\frac{1}{4}$	1.309	11
1 $\frac{1}{2}$	1.650	11
1 $\frac{3}{4}$	1.882	11
2	2.116	11
	2.347	11

FUELS

662.6

Quality.—A good aircraft internal combustion engine fuel should fulfil the following requirements:—

1. It should enable the engine to start easily from cold.
2. Its specific gravity and calorific value should be within the limits stated.
3. It should not cause excessive deposits in the cylinders or on the valves under any of the various conditions of running.
4. The consumption must be economical.

At the present time there are three fuels that are practicable for aeroplane engines, viz., petrol, benzol, and alcohol (mixture). From a purely thermal standpoint, there is very little to choose between them, though the better grades of petrol are almost universally employed.

HEAT VALUES OF FUELS

		Calories	B.Th.U.	H.P.
Petrol	- - - 1 kg.	= 11,000	= 43,500	per hour = 17.1
"	- - - 1 pt.	= 4,500	= 17,800	" = 7.0
"	- - - 1 lb.	= 4,800	= 18,900	" = 7.50

HEAT VALUES OF FUELS—*Continued*

			Ft.-Lbs.	H.P.
Petrol	-	1 lb.	= 15,000,000	per hour = 7.50
Benzol	-	1 "	= 14,000,000	" = 7.00
Paraffin	-	1 "	= 18,000,000	" = 9.00
Coal	-	1 "	= 12,000,000	" = 6.00
Alcohol, 100 per cent.	1	"	= 9,800,000	" = 5.00
Methylated, 83	"	1 "	= 8,600,000	" = 4.30
Gas (coal)	-	1 cub. ft.	= 550,000	" = 0.28
B.Th.U.				
Hydrogen	-	1 lb.	= 53,340	burnt to steam.
Carbon	-	1 "	= 4,450	" CO.
"	-	1 "	= 10,170	" from CO to CO ₂

WEIGHT OF FUELS

	Specific Gravity	Weight of 1 Cub. Ft. (Lbs.)	Weight of 1 Cub. In. (Lbs.)
(Water)	(1.00)	(62.425)	(.036)
Alcohol, absolute	0.792	49	.028
" proof	0.916	57	.033
Benzene	0.900	56	.033
Ether	0.716	45	.028
Paraffin, American	0.815	51	.029
" Russian	0.825	52	.030
Petrol	0.70	44	.025
Petroleum, Penn., heavy	0.886	55	.032
" Caucasian, heavy	0.938	59	.034
" " light	0.884	55	.032
" refuse	0.938	59	.034

If the nature or source of the fuel is known, the calorific value can always be estimated within 5 per cent. without knowing the exact composition of the fuel (G. H. Baillie).

A *B.Th.U.*, or British thermal unit, is the amount of heat required to raise 1 lb. of pure water 1° F. from 39.1° F. to 40.1° F. (the temperature at which the density of water is a maximum).

The mechanical work which can be performed by the dissipation of one *B.Th.U.* is 778 ft.-lbs.

Petrol Fuel

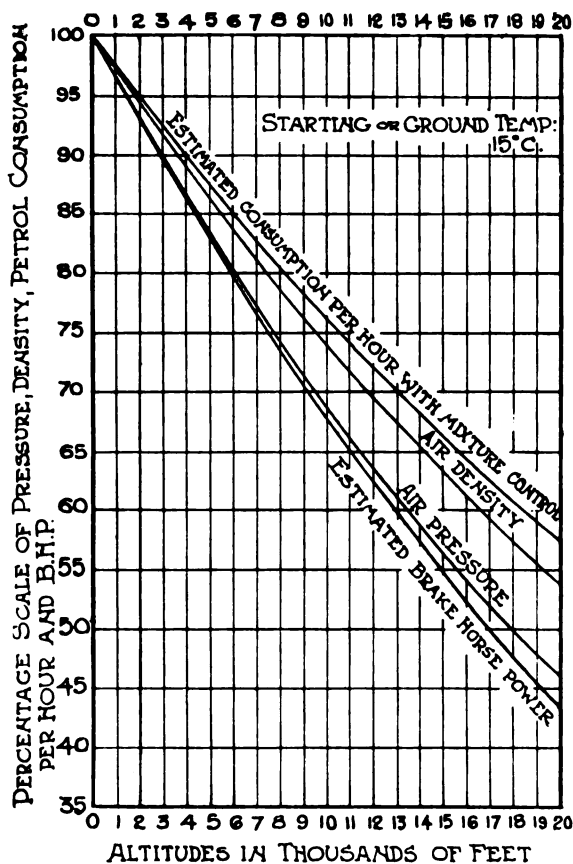
Petrol is obtained by the process of distillation from crude petroleum. The latter is of a highly complex character, containing many more or less volatile hydrocarbons, its exact composition varying according to the locality in which it is found. The derived product, petrol, which comes off in the earlier stages of distillation, is also of a complex character, and consists of a mixture of various members of the paraffin series, expressed by the general chemical formula, C_nH_{2n+2} , where n is any integer.

Commercial petrol should have a specific gravity of 0.68 to 0.76, and should consist mostly of Hexane (C_6H_{14}), Heptane (C_7H_{16}), and Octane (C_8H_{18}). The lower the specific gravity of the petrol the higher is the amount of energy per pound, since the proportion of hydrogen to carbon is higher in the earlier members of the paraffin series, as can be seen readily from the formula given above. It should be completely volatile in the air without the aid of artificial heat.

Petrol for use in aircraft engines should be as free as possible from cracked spirit, and should show an iodine value of not more than 7. Further, it should be clear, colourless, and free from undissolved water; its specific gravity should not exceed 0.725 at 15° C. The distillation range must be such that when 100 c.c. of the petrol are distilled in a standard distillation apparatus at 760 mm. pressure, and at the rate of two drops per second, 10 per cent. should collect below 74° C., 65 per cent. at or below 100° C., and the remainder to be completely volatilised at or below 150° C. As regards acidity, a suitable test is the shaking of 100 c.c. of the petrol with 10 c.c. of neutral distilled water, and one drop of N/10 caustic soda should be added, then the aqueous layer should impart a pink coloration to phenolphthalein. A test should also be made for sulphur content, which should be less than 0.01 per cent. This test is carried out by boiling 10 c.c. of alcohol and a few drops of ammonia. On adding silver nitrate solution to this mixture, a brown coloration will appear if the sulphur content is over the stipulated quantity.

Calorific Value.—The calorific value of petrol is 18,500 to 21,000 B.Th.U. per lb., that is to say, the complete combustion of 1 lb. of the fuel will release from 18,500 to 21,000 British thermal units of heat.

Thermal Efficiency.—Taking the calorific value of petrol at 19,000 B.Th.U. per lb., since the mechanical work which can be performed by the dissipation of 1 B.Th.U. is 778 ft.-lbs., it follows that if all the heat could be utilised the combustion of 1 lb. of petrol would result in the performance of $19,000 \times 778 = 14,782,000$ ft.-lbs. of work.



CURVES SHOWING ESTIMATED PERCENTAGE DECREASE
IN PETROL CONSUMPTION, B.H.P., AIR PRESSURE AND AIR
DENSITY FOR ALTITUDES UP TO 20,000 FEET.

According to the above, the petrol consumed in the engine per hour for each B.H.P., taken at 75 lb., represents 11,086,500 ft.-lbs. of work. As a horse-power represents $33,000 \times 60 = 1,980,000$ ft.-lbs. per hour, the heat in 75 lb. of petrol represents 5.6 H.P. exerted for one hour. Since the quality of fuel used represents 5.6 H.P. hours, and only 1 B.H.P. hour is obtained for it, the ratio of the heat utilised is to the total heat in the fuel as 1 : 5.6, approximately 18 : 100. The thermal efficiency of the engine is therefore about 18 per cent.

Fuel Alcohol

662.752

Pure alcohol, while presenting many attractive features, has failed to establish itself universally as a fuel for internal combustion engines. However, the prospects of certain alcohol mixtures are very promising, as they reproduce the self-starting, non-corrosive, and other good qualities of petrol, combined with the property that pre-ignition does not take place until the compression is in the neighbourhood of 200 lbs. per sq. in., which is over double that of petrol. It is this feature of the possibility of high compression that makes this fuel worthy of consideration for aircraft engines. For at normal pressures the weight of alcohol consumed per B.H.P. is greater than that of petrol

	Petrol.	Alcohol Mixture.
Maximum pre-ignition compression in pounds per square inch	80-90	180-200
Increase in horse-power—		
At normal compression - - -	...	10 %
At high compression - - -	...	30 %
Efficiency - - -	16.20 %	28.31 %
Explosive mixtures - - -	2.5 %	4.13.5 %
Increase in products of combustion -	5.4 %	6.5 %
Specific gravity - - -	0.72	0.812
B.Th.U. per cubic foot - - -	9,300,000	8,920,000
Calorific value (higher) in B.Th.U. -	20,280	12,033
Air required for combustion of 1 lb. of fuel	14.992 lbs.	8.086 lbs.

An example of a modern tried alcohol mixture is "Ethol" :—

Ethyl alcohol (95 per cent. pure)	- -	86 per cent.
Ethyl ether	- -	10 "
Wood spirit	- -	1 "
Benzol	- -	3 "

Motor fuels having alcohol as a base have been in use in Germany for some time, and appear to work well. An example is:—

Hydrated ethyl alcohol	-	-	-	-	96.75 per cent.
Impure methyl alcohol (wood spirit)	-	-	-	-	0.75 „
Acetone	-	-	-	-	0.25 „
Pyridine	-	-	-	-	0.25 „
Benzol	-	-	-	-	2 „

An alternative is 50 per cent. each of alcohol and benzol.

*D.E.D.A. (Detachable Data) System
R. B. Chase Matthews. Patents provisionally protected. U.S. Patents applied for.*

STANDARD METAL PARTS FOR AIRCRAFT

The dimensions of these small parts were originally decided upon as the outcome of the experience of, and tests carried out by, the R.A.F., Farnborough (now the Royal Aircraft Establishment). With some slight modifications, they have now been adopted as the standard for all British aeroplane work. These standards are colloquially known as "A.G.S." parts. Certain aircraft manufacturing firms have also compiled lists of their own to supplement the recognised standards. Such lists are, of course, special, and do not in any way purport to be universal in character.

A number of small changes have again been made, recently, in standard A.G.S. parts. These alterations have chiefly affected the specification of the material to be used (e.g., high tensile steel is replaced by mild steel wherever possible), and in the slight variation of maximum dimensions (so that the parts may be manufactured from standard material with a minimum of machining). This explains the recent changes in fork ends, universal fork joints, and turnbuckles. In the case of bolts and nuts, the variety of different lengths has been reduced with a view to facilitating production. For convenience in reference, the tables, which follow, show both the old and the corresponding new types arranged side by side.

To facilitate reference to A.G.S. parts generally,

(I.) An alphabetical and also
(II.) A numerical index has been placed at the commencement, which shows all the A.G.S. parts usually included, together with their identification numbers. Following this, are grouped details of:—

- (III.) Cables, wires, and standard fittings.
- (IV.) Bolts, studs, nuts, and rivets.
- (V.) Wires, wire ropes, and streamline wires.
- (VI.) Fork ends, turnbuckles, shackles, etc.
- (VII.) Tubes.

These are all arranged in a concise and convenient form, and include a number of original charts, specially prepared for this book. As detailed dimensions of the parts most generally required in combinations, such as bolts, nuts, turnbuckles, etc., are included, these tables should therefore be of material assistance to both designers and manufacturers.

In a number of instances, the tables show combinations of standard parts which are frequently required in conjunction with one

another, e.g., a table is given which shows the cables, turnbuckles, thimbles, shackles, etc., which fit together to form a complete unit. Tables are also incorporated which show the sizes of steel bar; also tables are provided for a number of the more usual standard parts, giving the lengths and the weights of bar required to make 1,000 pieces. The allowance made for waste and parting off is clearly stated in each case, so that where workshop practice differs the necessary corrections may be made readily. These tables should be of assistance to manufacturers when ordering material.

*DL-1 (Detachable Link) System
R. B. Shaw-Mather. Patent (privately protected) U. S. Patents applied for*

STANDARD METAL PARTS FOR AEROPLANES

(I.) Alphabetical Index of A.G.S. Numbers

Title.	A.G.S. No.
Air cock, 3-way -	290.
„ relief valve (superseded by A.G.S. 292) -	235.
„ „ -	292.
Baffle-plate fastener -	389.
Ball joints -	385.
Bolts, hexagon (superseded by Spec. 2A. 1) -	101 to 112.
Burrs -	190 and 191.
Bushes, fibre -	281.
Cables, flexible (superseded by Spec. 2W. 2) -	135.
Capacity plates -	226.
Clips for rubber pipes (superseded by A.G.S. 208) -	237.
„ „ -	208.
„ spring -	374.
„ for tubes -	386.
„ for fairing -	387.
„ for cable -	388.
Connections, petrol tank -	220 and 225.
„ rubber pipe -	236.
Cocks, oil and water (superseded by A.G.S. 365) -	223.
„ petrol, 3-way disc -	293.
„ „ $\frac{1}{4}$ in., $\frac{3}{8}$ in., and $\frac{1}{2}$ in. B.S.P. (super- seded by A.G.S. 408 to 410) -	367 to 369.
„ „ $\frac{1}{4}$ in., $\frac{3}{8}$ in., and $\frac{1}{2}$ in. B.S.P. disc -	408 to 410.
Cock drain, $\frac{1}{2}$ in. B.S.P. -	365.
Eyelets (superseded by Specification S.P. 2) -	232.
Eye bolts (superseded by Specification 2A. 3) -	122 to 125.
Ferrules for solid wires -	156.
Filters, petrol and oil -	233 and 234.
„ „ „ seating -	243.
„ „ (superseded by A.G.S. 203 to 205) -	229 to 231.
„ „ -	203 to 205.
„ „ details -	275.
„ „ for tanks -	371 to 373.
Flanges, male -	214.
„ female -	215.
„ for flexible pipe -	282.
Fork joints, H.T.S. (superseded by A.G.S. 412 to 422) -	168 to 178.
„ „ M.S. -	412 to 422.
Forked links -	398 to 404.
Indicator plates -	291, 294, and 295.
Links for duplicating cables -	395.
Locking-wires -	154 and 165.
Lock-washers -	194 and 195.

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ALPHABETICAL INDEX OF A.G.S. NUMBERS—Continued

	Title.	A.G.S. No.
Lock-nuts, union steel	- - - -	207.
" " brass	- - - -	224.
Nipples, spherical (superseceded by A.G.S. 209)	- - - -	210.
" " " "	- - - -	209.
" " for flexible pipe connections	- - - -	211.
Nuts, hexagon R.H. thread (superseceded by Specification 2A. 1)	- - - -	114 to 119.
" " L.H. thread (superseceded by Specification 2A. 1)	- - - -	238 and 239.
" wing	- - - -	113 and 120.
" union	- - - -	212.
Pins (superseceded by A.G.S. 383)	- - - -	137 and 382.
" for duplicating link	- - - -	396.
" " " "	- - - -	383 and 384.
Pipes, flexible, with fittings (superseceded by A.G.S. 277 to 279)	- - - -	240 to 242.
" " with fittings	- - - -	277 to 279.
Plugs	- - - -	216.
Pulleys	- - - -	375 to 380.
R.A.F. wires with fork joints (superseceded by Specification 2W. 3)	- - - -	320 to 330.
" " with universal fork joints (superseceded by Specification 2W. 3)	- - - -	346 to 356.
" " (superseceded by Specification 2W. 3)	- - - -	197, 198, 200, 201.
" " with M.S. fork joints (superseceded by Specification 2W. 3)	- - - -	438 to 448.
" " with M.S. universal fork joints (superseceded by Specification 2W. 3)	- - - -	464 to 474.
Rivets	- - - -	259 to 261, 397.
Screws, B.A.	- - - -	244 to 249.
Seats	- - - -	264.
Shackles	- - - -	158.
Split-pins	- - - -	166.
Studs (<i>see summary following</i>)	- - - -	130 to 133.
Sumps	- - - -	219.
Taper-pins	- - - -	167.
" split	- - - -	213.
T.-pieces for flexible pipe connection	- - - -	276.
Thimbles	- - - -	136.
Tie-rods (superseceded by Specification 2W. 8)	- - - -	183 to 185.
" with fork joints (superseceded by Specification 2W. 8)	- - - -	307 to 317.
" with M.S. fork joints (superseceded by Specification 2W. 8)	- - - -	177 to 481.

LiE-1-A (Detachable Data) System
& Karlase Mathers' Patents (personally protected). U.S. Patents applied for

Cresby Lockwood & Son's TECHNICAL DATA SERIES.

(II.) Numerical Index of A.G.S. Parts

22 ;

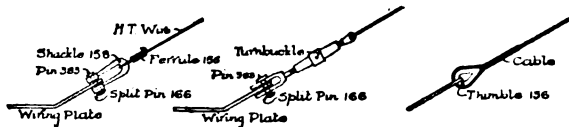
NUMERICAL INDEX OF A.G.S. PARTS—*Continued*

A.G.S. No.	Title.
194 to 195.	Lock-washers.
197 to 201.	R.A.F. wires (superseded by Specification 2W. 3).
203 to 205.	Filters, petrol.
207.	Lock-nuts, union steel.
208.	Clips for rubber pipes.
209.	Nipples, spherical.
210.	" " (superseded by A.G.S. 209).
211.	" " for flexible pipe connections.
212.	Nuts, union.
213.	Taper-pins, split.
214.	Flanges, male.
215.	" " female.
216.	Plugs.
217.	Unions for flexible pipe.
218.	" "
219.	Sumps.
220.	Connections, petrol tank.
223.	Cocks, oil and water (superseded by A.G.S. 365).
224.	Lock-nuts, union brass.
225.	Connections, petrol tank.
226.	Capacity plates.
229 to 231.	Filters, petrol (superseded by A.G.S. 203 to 205).
232.	Eyelets (superseded by Specification S.P. 2).
233 to 234.	Filters, petrol and oil.
235.	Air relief valve (superseded by A.G.S. 292).
236.	Connections, rubber pipe.
237.	Clips for rubber pipes (superseded by A.G.S. 208).
238 to 239.	Nuts, hexagon L.H. thread (superseded by Specification 2A. 1).
240 to 242.	Pipes, flexible, with fittings (superseded by A.G.S. 277 to 279).
243.	Filters, petrol and oil seating.
244 to 249.	Screws, B.A.
250 to 253.	Wood screws.
259 to 261.	Rivets.
264.	Seats.
267 to 268.	Tubes, H.T.S.
275.	Filters, petrol details.
276.	Taper pieces for flexible pipe connection.
277 to 279.	Pipes, flexible, with fittings.
281.	Bushes, fibre.
282.	Flanges for flexible pipe.
290.	Air cock, 3-way.
291.	Indicator plates.
292.	Air relief valve.
293.	Cocks, petrol, 3-way disc.

NUMERICAL INDEX OF A.G.S. PARTS—Continued

A.G.S. No.	Title.
294 to 295.	Indicator plates.
307 to 317.	Tie-rods with fork joints (superseded by Specification 2W. 8).
320 to 330.	R.A.F. wires with fork joints (superseded by Specification 2W. 3).
333 to 343.	Universal fork joints, H.T.S. (superseded by A.G.S. 451 to 461).
346 to 356.	R.A.F. wires with universal fork joints (superseded by Specification 2W. 3).
367 to 369.	Cocks, petrol, $\frac{1}{4}$ in., $\frac{3}{8}$ in., and $\frac{1}{2}$ in. B.S.P. (superseded by A.G.S. 408 to 410).
371 to 373.	Filters, petrol, for tanks.
374.	Clips, spring.
375 to 380.	Pulleys.
382.	Pins (superseded by A.G.S. 383).
383 to 384.	Pins.
385.	Bell joints.
386.	Clips for tube.
387.	„ for fairing.
388.	„ for cable.
389.	Baffle-plate fastener.
390 to 391.	Washer-plate.
395.	Links for duplicating cables.
396.	Pins for duplicating link.
398 to 404.	Forked links.
408 to 410.	Cocks, petrol, $\frac{1}{4}$ in., $\frac{3}{8}$ in., and $\frac{1}{2}$ in. B.S.P. disc.
412 to 422.	Fork joints, M.S.
438 to 448.	R.A.F. wires with M.S. fork joints (superseded by Specification 2W. 3).
451 to 461.	Universal fork joints, M.S.
464 to 474.	R.A.F. wires with M.S. universal fork joints (superseded by Specification 2W. 3).
490 to 498.	Turnbuckles, M.S.
506 to 508.	„ „ (short).

(III.) Cables, Wires, and Standard Fittings



The above diagram is to illustrate the table on the next page.

CABLES, WIRES, AND STANDARD FITTINGS

[illegible]

Note.—The effective strength of the cable is reduced 10 to 25 per cent. by the splice.

DE-DA (Detachable Data) System
R. Borlase Matthews' Patents (provisionally protected). U.S. Patents applied for.

(IV.) Bolts, Studs, Nuts, and Rivets

BRIGHT AIRCRAFT STEEL BOLTS AND NUTS

Specifications.—*Material*—S.1 for medium carbon, bright rolled or drawn steel bars (see summary at the beginning of this Division). *Parts*, 2 A.1 for bright steel bolts and nuts (see abstract which follows).

Dimensions.—*Shanks*—up to $\frac{1}{2}$ in. B.S.F., the diameter limits are +0 and -0.003 in.; for $\frac{1}{2}$ in. B.S.F. and above, the limits are +0 and -0.004 in. The corners under the heads of the bolts are rounded to a radius of 0.03 in., except for the 4 B.A. and 2 B.A. sizes; in these cases, the radius is 0.02 in. The standard lengths in in. (with limits of ± 0.02 in.) are as follows:—

Mark,	B	C	D	E	G	I	K	M	O	Q	S	U	W	X	Y
Length,	0.4	0.6	0.8	1.0	1.4	1.8	2.2	2.6	3.0	3.5	4.0	4.5	5.0	5.5	6

Threads and other Parts are in accordance with B.E.S.A. specifications Nos. 20 and 54 (see tables herewith entitled "Aircraft Standard Bolts and Nuts" and "Aircraft Castle Nuts," in which the particulars given in the said specifications are incorporated. In another separate table, the standard lengths are given of the threaded portions of the shanks (limits ± 0.02 in.).

Tests.—*Tensile*—not less than 35 tons per sq. in. (area taken at the bottom of the thread). *Bending*—any test bolt must stand doubling over, without cracking, when cold, until the internal radius is equal to the diameter of the bolt and the sides are parallel.

Bolts, Studs, Nuts, and Rivets—Continued

AIRCRAFT STANDARD BOLTS AND NUTS

(Based on B.E.S.A. Specifications Nos. 20, 54, etc.).

Dia.	Screw Threads.		Hex. Nuts and Bolt Heads (Bright).							
	No. of Threads per Inch.	Pitch.	Width Across Flats. Max. Min.	Width Across Corners Approx. Min.	Thickness (Max.-Min.).					
					Nuts, Ord.	Lock Nuts.	Bolt Heads.	Slotted Nuts.		
								Thick- ness.	Slot.	
									Width.	Depth.
4	38.5	.0260	.280 .275	.323	.16 .15	.16 .15	.13 .12	...	...	...
2	31.4	.0319	.338 .333	.390	.19 .18	.19 .18	.13 .12	.25 .24	.08	.09
B.S.F. $\frac{1}{4}$ "	26	.03846	.445 .440	.515	.21 .20	.16 .15	.16 .15	.26 .25	.09	.09
$\frac{3}{8}$ "	26	.03846	.525 .520	.61	.26 .25	.18 .17	.23 .22	.32 .31	.09	.09
$\frac{5}{16}$ "	22	.04545	.525 .520	.61	.26 .25	.20 .19	.23 .22	.32 .31	.12	.13
$\frac{1}{2}$ "	22	.04545	.600 .595	.69	.32 .31	.22 .21	.28 .27	.39 .38	.12	.13
$\frac{3}{4}$ "	20	.05000	.600 .595	.69	.32 .31	.24 .23	.28 .27	.39 .38	.12	.13
$\frac{1 1}{8}$ "	20	.05000	.710 .705	.82	.39 .38	.26 .25	.34 .33	.45 .44	.15	.18
$\frac{7}{8}$ "	18	.05556	.710 .705	.82	.39 .38	.28 .27	.34 .33	.45 .44	.15	.18
$\frac{1 1}{2}$ "	18	.05556	.710 .705	.82	...	.28 .27	...	...	.15	.18
$\frac{1 3}{4}$ "	16	0.6250	.820 .815	.95	.45 .44	.32 .31	.39 .38	.51 .50	.15	.18

N.B.—The use of the 32nd sizes should be avoided as far as possible.

Bolts, Studs, Nuts, and Rivets—Continued

LENGTHS OF THREADS ON STANDARD AIRCRAFT BOLTS

Standard Bolt Lengths (Without Heads).	Size.	4 B.A.	2 B.A.	$\frac{1}{4}$ in.	$\frac{5}{16}$ in.	$\frac{3}{8}$ in.	$\frac{7}{8}$ in.	$\frac{1}{2}$ in.
	Part No.	102	103	105	107	109	111	112
In.	Mark.	In.	In.	In.	In.	In.	In.	In.
0.4	B	.35	.35	.35	.35	...	...	...
0.6	O	.45	.50	.55	.60	.55	...	...
0.8	D	.45	.50	.55	.60	.65	.70	.75
1.0	E	.45	.50	.55	.60	.65	.70	.75
1.4	G	.65	.70	.75	.80	.85	.90	1.00
1.8	I	.65	.70	.75	.80	.85	.90	1.00
2.2	K	.65	.70	.75	.80	.85	.90	1.00
2.6	M	.65	.70	.75	.80	.85	.90	1.00
3.0	O	.65	.70	.75	.80	.85	.90	1.00
3.5	Q	.70	.80	.80	.90	.95	1.05	1.10
4.0	S	.70	.80	.80	.90	.95	1.05	1.10
4.5	U	.70	.80	.80	.90	.95	1.05	1.10
5.0	W	.70	.80	.80	.90	.95	1.05	1.10
5.5	X	1.00	1.00	1.00	1.00	1.00	1.05	1.10
6.0	Y	1.00	1.00	1.00	1.00	1.00	1.05	1.10

Standard Bolt Lengths (Without Heads).	Size.	$\frac{9}{16}$ in.	$\frac{5}{8}$ in.	$1\frac{1}{8}$ in.	$\frac{3}{4}$ in.	$1\frac{3}{8}$ in.	$\frac{7}{8}$ in.	$1\frac{5}{8}$ in.	1 in.
	Part No.	1,001	1,002	1,003	1,004	1,005	1,006	1,007	1,008
In.	Mark.	In.	In.	In.	In.	In.	In.	In.	In.
1.0	E	.90	.90	.90	.90	.90	...	...	...
1.4	G	1.00	1.0	1.0	1.10	1.10	1.20	1.20	1.20
1.8	I	1.00	1.0	1.0	1.10	1.10	1.30	1.30	1.30
2.2	K	1.00	1.0	1.0	1.10	1.10	1.30	1.30	1.30
2.6	M	1.00	1.0	1.0	1.10	1.10	1.30	1.30	1.30
3.0	O	1.00	1.0	1.0	1.10	1.10	1.30	1.30	1.30
3.5	Q	1.10	1.1	1.1	1.20	1.20	1.40	1.40	1.40
4.0	S	1.10	1.1	1.1	1.20	1.20	1.40	1.40	1.40
4.5	U	1.10	1.1	1.1	1.20	1.20	1.40	1.40	1.40
5.0	W	1.10	1.1	1.1	1.20	1.20	1.40	1.40	1.40
5.5	X	1.10	1.1	1.1	1.20	1.20	1.40	1.40	1.40
6.0	Y	1.10	1.1	1.1	1.20	1.20	1.40	1.40	1.40

Example.—A $\frac{1}{4}$ -in. B.S.F. Bolt, Part No. 105M (which has a shank 2.6 in. in length), is threaded for 0.75 in. It is important to always quote the Mark (which indicates the length of the shank) with the Part No.

Bolts, Studs, Nuts, and Rivets—Continued**A.G.S. BOLT AND NUT PART NUMBERS**

In the foregoing tables, bolts and nuts have been indicated by their threads. It is often more convenient to employ the A.G.S. numbers. This table affords a ready means of ascertaining them.

Thread.	Bolts. Part Nos.	Nuts (Ordinary). Part Nos.	Lock Nuts. Part Nos.	Slotted Nuts. Part Nos.
		R.H. Mark.	R.H. Mark. L.H.	R.H. Mark.
4 B.A.	102	115 C	115 C 238	...
2 B.A.	103	115 B	115 B 238	114 B
$\frac{1}{2}$	105	116 A	117 A 239	118 A
$\frac{5}{16}$	107	116 C	117 C 239	118 C
$\frac{3}{8}$	109	116 E	117 E 239	118 E
$\frac{7}{16}$	111	116 G	117 G 239	118 G
$\frac{1}{2}$	112	116 H	117 H 239	118 H
$\frac{5}{8}$	1,001	116 J	117 J 239	118 J
$\frac{3}{4}$	1,002	116 K	117 K 239	118 K
$\frac{7}{8}$	1,003	116 L	117 L 239	118 L
$1\frac{1}{8}$	1,004	116 M	117 M 239	118 M
$1\frac{1}{4}$	1,005	116 N	117 N 239	118 N
$1\frac{3}{8}$	1,006	116 P	117 P 239	118 P
$1\frac{1}{2}$	1,007	116 Q	117 Q 239	118 Q
1	1,008	116 R	117 R 239	118 R

* The marks should always be quoted with these numbers, so as to specify the length required.

AIRCRAFT CASTLE NUTS

Thread.	Part No.	Total Thickness.		Thickness of Hexagon.	Dia. of Castle Portion.	Radius of Edge.	Slot.	
		Max. In.	Min. In.	In.	In.	In.	Width.	Depth.
$\frac{1}{2}$	119 A	.32	.32	.188	.38	.03	.09	.11
$\frac{5}{16}$	119 C	.39	.38	.234	.46	.03	.12	.135
$\frac{3}{8}$	119 E	.47	.46	.281	.535	.05	.12	.165
$\frac{7}{16}$	119 G	.55	.54	.328	.645	.05	.15	.19
$\frac{1}{2}$	119 H	.63	.62	.375	.755	.06	.15	.22

Note.—The bottoms of the slots may be made rectangular or rounded.

MATERIAL REQUIRED TO MAKE 1,000 HEX. BOLTS TO SPEC. 2A.1 **MATERIAL—35 TONS MILD STEEL TO SPEC. S.1, Pt. 1. (Approximate)**

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Size.		4 B.A.	2 B.A.			$\frac{1}{2}$ In. B.S.F.	$\frac{3}{8}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{3}{4}$ In. B.S.F.	$\frac{1}{2}$ In. H.S.F.		$\frac{1}{2}$ In. B.S.F.	$\frac{3}{4}$ In. B.S.F.		$\frac{1}{2}$ In. B.S.F.
Hex. Bar.	Width a/f In.	280	338			445	525			800		710		820	
	Wt. per Ft. Run, Lbs.	231	337			539	912			106		1485		198	
A.G.S. No.		102	103			105	107			109		111		112	
Length A. In.	Part No.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.
4	B	70	16	72	24	74	44	80	66	103	109	126	187	131	260
6	C	88	20	90	30	92	54	98	80	121	128	145	216	150	297
8	D	106	25	108	36	110	65	116	94	140	149	176	270	186	368
10	E	125	29	127	43	129	76	135	110	176	187	217	323	222	440
14	G	161	37	163	55	165	97	171	139	212	225	254	378	259	513
18	I	197	46	199	67	201	118	207	168	249	264	290	431	295	585
22	K	234	54	236	80	238	140	244	198	285	302	326	485	331	656
26	M	270	62	272	92	274	162	280	227	367	390	372	553	377	747
30	O	306	71	308	104	310	183	316	256	412	437	417	620	422	837
35	Q	352	81	354	119	356	210	362	294	458	486	463	688	468	927
40	S	397	92	399	135	401	236	407	331	503	534	508	755	513	1,016
45	U	443	102	445	150	447	264	453	368	548	582	553	822	558	1,105
50	W	488	113	490	165	492	290	498	405	593	629	598	888	603	1,194
55	X	533	123	535	181	537	317	543	441						
60	Y	578	134	580	196	582	343	588	478						

Note.—0.25 in. has been allowed for "parting-off," and 6 in. waste on each 6 ft. bar of steel.
 L = Length, W = Weight per 1,000.

MATERIAL REQUIRED TO MAKE 1,000 HEX. BOLTS TO SPEC. 2A.1—(Continued)
MATERIAL—35 TONS MILD STEEL TO SPEC. S.1, Pr. 1. (Approximate)

Length A. In.	Size	A.G.S. No.	17	18	19	20	21	22	23	24	25	26
			$\frac{1}{2}$ In. B.S.F.	$\frac{3}{4}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{3}{4}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{3}{4}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{3}{4}$ In. B.S.F.	L. Ft.	W. Lbs.
Hex. {	Width a/c In.											
Bar. {	Wt. per Ft. Run, Lbs.											
			920		1010		1200		1300		1480	
			249		305		425		572		646	
			1,001		1,002 and 1,003		1,004 and 1,005		1,006 and 1,007		1,008	
			L. Ft.	W. Lbs.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.
B			...	...	...	...	...	...	...	...	...	...
C			...	...	...	...	...	...	...	...	...	...
D			...	...	...	...	...	...	...	...	...	...
E			155	386	160	489	169	720	...	...	...	...
F			191	476	196	508	205	870	216	1,240	221	1,430
G			227	506	232	708	241	1,030	252	1,440	257	1,690
I			264	658	269	822	278	1,180	289	1,650	294	1,900
K			300	747	305	932	314	1,340	325	1,800	330	2,130
M			336	883	341	1,040	350	1,490	361	2,070	366	2,370
Q			382	952	387	1,180	396	1,680	407	2,330	412	2,660
S			427	1,065	432	1,340	441	1,880	452	2,590	457	2,960
U			473	1,180	478	1,490	487	2,070	498	2,850	503	3,250
W			518	1,290	523	1,600	532	2,290	543	3,110	548	3,540
X			563	1,400	568	1,730	577	2,490	588	3,370	593	3,830
Y			608	1,515	613	1,870	622	2,650	633	3,620	638	4,120

Note.—0.25 in. has been allowed for "parting-off," and 6 in. waste on each 6 ft. bar of steel.
 L = Length, W = Weight per 1,000.

DE-DA (Detachable Data) System
R. Barlow Matthews' Patents (provisionally protected). U.S. Patents applied for.

MATERIAL REQUIRED TO MAKE 1,000 HEX. NUTS TO SPEC. 2A.1
MATERIAL—35 TONS MILD STEEL TO SPEC. S.1, Pt. 1. (Approximate)

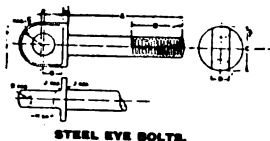
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
HEX. BAR.		A.G.S. No. =		114	115 and 238	115 and 238	116	117 and 239	118	119					
Width a/f. Max.	Weight per Foot Run.	Thread.	Part. No.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.
Ins.	Lbs.	4 B.A.	C	...	...	...	...	...	...	...	...	...	...	...	...
280	231	2 B.A.	B	34	12	26	6	26	10	26	18	31	...	...	...
338	337	B.S.F.	A	...	...	...	...	...	...	...	...	...	...	...	...
445	589	1 In.	A	...	...	...	...	...	...	...	...	...	...	...	...
525	812	3/4	B	...	...	...	...	...	...	...	...	...	...	...	...
525	812	1 1/4	C	...	...	...	...	...	...	...	...	...	...	...	...
600	106	1 1/2	D	...	...	...	...	...	...	...	...	...	...	...	...
600	106	1 3/4	E	...	...	...	...	...	...	...	...	...	...	...	...
710	145	2	F	...	...	...	...	...	...	...	...	...	...	...	...
710	145	2 1/4	G	...	...	...	...	...	...	...	...	...	...	...	...
820	198	2 3/4	H	...	...	...	...	...	...	...	...	...	...	...	...
920	249	3	I	...	...	...	...	...	...	...	...	...	...	...	...
1010	305	3 1/2	J	...	...	...	...	...	...	...	...	...	...	...	...
1010	305	4	K	...	...	...	...	...	...	...	...	...	...	...	...
1200	425	4 1/2	L	...	...	...	...	...	...	...	...	...	...	...	...
1200	425	5	M	...	...	...	...	...	...	...	...	...	...	...	...
1300	572	5 1/2	N	...	...	...	...	...	...	...	...	...	...	...	...
1300	572	6	P	...	...	...	...	...	...	...	...	...	...	...	...
1480	646	6 1/2	Q	...	...	...	...	...	...	...	...	...	...	...	...
1480	646	7	R	...	...	...	...	...	...	...	...	...	...	...	...

Note.—0.125 in. has been allowed for "parting-off," and 6 in. waste on each 6 ft. bar of steel. L = Length, W = Weight per 1,000.

Bolts, Studs, Nuts, and Rivets—Continued**STEEL EYE BOLTS**

Specifications.—*Material*—S.1. (Part 1) as for bright steel bolts and nuts. *Part 2* A.3 for bright steel eye bolts (see particulars which follow).

Dimensions.—With the exception of the heads, these are similar to those of the bright steel bolts; shank diameter limits, shank lengths (and marks), thread lengths, etc., are identical. Reference should therefore be made to tables entitled "Aircraft Standard Bolts and Nuts" and "Lengths of Threads on Standard Aircraft Bolts."

**STEEL EYE BOLTS.**

(See Table on next page)

D.E. DA (Detachable Data) System
K. Borlase Matthews' Patents provisionally protected. U.S. Patents applied for.

Bolts, Studs, Nuts, and Rivets—Continued

621.88

Size of Bolt.	Part No.	C + .01 In. D - .01 In.	D + .01 In. D - .01 In.	E + .01 In. E - .01 In.	F + .01 In. F - .01 In.	G + .01 In. G - .01 In.	H + .01 In. H - .01 In.	J + .01 In. J - .01 In.	K + .01 In. K - .01 In.	Minimum Failing Loads.	Size of Suitable Cable.
		In.	In.	In.	In.	In.	In.	In.	In.	Lbs.	Cwt.
4 B.A.	121	.31	.12	.04	.04	.15	.17	.02	.15	750	5
2 "	122	.43	.16	.04	.04	.20	.22	.03	.14	1,320	10
1 in.	123	.56	.20	.06	.04	.25	.27	.03	.15	2,480	15
1 1/8 "	124	.68	.27	.08	.04	.30	.35	.03	.20	3,980	20
1 1/4 "	125	.87	.35	.10	.04	.35	.45	.03	.25	5,960	25
1 1/2 "	126	.93	.39	.10	.04	.40	.47	.03	.25	8,290	35
1 3/4 "	127	1.00	.42	.12	.04	.45	.50	.03	.30	10,860	45
2 "	128	1.12	.50	.12	.06	.50	.62	.03	.35	14,300	60
2 1/4 "	129	1.31	.58	.14	.06	.60	.75	.03	.40	17,500	75
2 3/4 "	1,021	1.50	.66	.14	.06	.70	.81	.03	.45	25,500	80

* It is important to always quote the mark (which indicates the length of the shank in inches) with the Part No.

Mark - - C D E G I K M O Q S U W X Y
Length - - 0.6 0.8 1.0 1.4 1.8 2.2 2.6 3.0 3.5 4.0 4.5 5.0 5.5 6

MATERIAL REQUIRED TO MAKE 1,000 EYE BOLTS TO SPEC. 2 A.3
MATERIAL—35 TONS MILD STEEL TO SPEC. S.1, Pr. 1. (*Approximate*)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Size =		4 B.A.		2 B.A.		$\frac{1}{4}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{3}{4}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	$\frac{1}{2}$ In. B.S.F.	
Dia. of Bar Req. =		$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	$\frac{1}{2}$ In.	
A.G.S. No. =		121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141
Length, A. Part, In.		L.	W.	L.	W.	L.	W.	L.	W.	L.	W.	L.	W.	L.	W.	L.	W.	L.	W.	L.	W.	L.
		Ft.	Lbs.	Ft.	Lbs.	Ft.	Lbs.	Ft.	Lbs.	Ft.	Lbs.	Ft.	Lbs.	Ft.	Lbs.	Ft.	Lbs.	Ft.	Lbs.	Ft.	Lbs.	Ft.
40	B	95	25	105	54	117	99	129	163	...	...	...	...	...	...	...	...	...	...	...	...	...
60	C	113	30	123	63	135	114	147	186	162	332	187	434	196	524	...	...	...	...	...	...	...
80	D	131	34	141	72	153	129	165	208	180	368	187	434	196	524	...	...	...	...	...	...	...
1-00	E	149	39	159	81	171	145	183	232	198	405	205	481	214	572	226	765	246	1140	...	...	...
1-40	G	186	49	196	100	208	176	220	278	235	481	242	568	251	670	263	890	283	1310	300	1800	...
1-80	I	222	58	232	118	244	206	256	324	271	555	278	652	287	767	289	1010	319	1480	336	2020	...
2-20	K	258	67	268	137	280	237	292	369	307	628	314	737	323	865	335	1134	355	1650	372	2240	...
2-60	M	284	77	304	156	316	267	328	415	343	702	350	822	339	964	371	1253	391	1810	408	2450	...
3-00	O	331	86	341	174	353	298	365	461	380	778	387	908	396	1058	408	1380	428	1980	445	2680	...
3-50	Q	377	99	387	198	399	338	411	520	426	872	433	1017	442	1180	454	1535	474	2200	491	2950	...
4-00	S	422	110	432	221	444	376	456	576	471	965	478	1120	487	1300	499	1687	519	2400	536	3220	...
4-50	U	...	...	...	...	489	414	501	633	516	1056	523	1230	532	1420	544	1840	564	2610	581	3500	...
5-00	W	...	...	...	...	535	452	547	692	562	1150	569	1336	578	1540	590	1993	610	2830	627	3770	...
5-50	X	...	...	...	...	580	490	592	748	607	1242	614	1440	623	1653	635	2150	655	3030	672	4040	...
6-00	Y	...	...	...	...	625	528	637	805	652	1334	659	1550	668	1782	680	2300	700	3240	717	4310	...
6-50	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7-0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Note. — 0.25 in. has been allowed for "parting-off," and 6 in. waste on each 6 ft. bar of steel. L = Length, W = Weight per 1,000.

Pat. 101 (Patentable Design) System

K. L. & Co. (Patentable Design) System

Specification.—*Material*—brass to Specification B.1, and mild steel to Specification S.1. Dimensions of screw heads, in accordance with B.E.S.A. Report No. 57.

Dimension.	Round Head.	Cheese Head.	Countersink Head.
Thickness of head	0·8 d.	0·75 d.	0·375 d.
Diameter of head	1·75 d.	1·75 d.	1·75 d.
Radius of head	0·8 d.	...	...
Angle of countersink	...	...	90 deg.
Slot :—			
Depth	0·4 d.	0·375 d.	0·375 d.
Width	0·2 d.	0·2 d.	0·2 d.
	+ 0·004 in.	+ 0·004 in.	+ 0·004 in.
A.G.S. No., brass	244	246	248
„ mild steel	245	247	249

Standard sizes used of the above screws: B.A. numbers, 0, 2, 4, 6, 8, and 10 by the following lengths in inches: $\frac{3}{16}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, 1, and $1\frac{1}{4}$.

Drawing for A & B Top

A.G.S. No.	H. Size of Thread. In.	C. Length of Thread. In. Limits $\pm$ '02.	E. Chamfer at Fixed End. In.	D. Dia. at End of Chamfer. In. Limits $\pm$ '02.
130	2 B.A.	0.4	0.05	0.14
131	$\frac{1}{4}$ B.S.F.	0.5	0.05	0.2
132	$\frac{5}{16}$ "	0.65	0.05	0.25
133	$\frac{3}{8}$ "	0.75	0.05	0.3

Specification.—S.1 Refers to bright aircraft steel bolts and nuts.

STANDARD AIRCRAFT STUDS—Continued

All Sizes Mark.	"A" Lengths. All Sizes. Limits $\pm .02$ in. In.	"B" Lengths. Limits $\pm .02$ in.			Material Required to Make 1,000 Pieces (Approximate).											
		130	131	132	$\frac{3}{8}$ B.S.F. In.	2 B.A.		$\frac{1}{4}$ in. B.S.F.		$\frac{1}{2}$ in. B.S.F.		$\frac{3}{8}$ in. B.S.F.		$\frac{1}{2}$ in. B.S.F.		
						L. Ft.	W. Lbs.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.	L. Ft.	W. Lbs.
B	.4	.35	.35	.35	...	89	8.4	98	16.4	111	29	...	...	...	...	
C	.6	.50	.55	.55	.65	107	10	116	19.4	130	33.8	139	52	139	52	
D	.8	"	"	"	"	125	11.7	134	22.4	148	38.5	157	59	157	59	
E	1.0	"	"	"	"	143	13.5	152	25.4	166	43.2	175	65.6	175	65.6	
F	1.2	"	"	"	"	161	15.2	170	28.5	184	48	183	72.6	183	72.6	
G	1.4	"	"	"	"	180	16.9	189	31.6	202	52.7	212	79.6	212	79.6	
H	1.6	"	"	"	"	198	18.6	207	34.6	220	57.5	230	86.4	230	86.4	
I	1.8	"	"	"	"	216	20.3	225	37.6	238	62.2	248	93.3	248	93.3	
J	2.0	"	"	"	"	234	22	243	40.6	257	67	266	100	266	100	
K	2.2	"	"	"	"	253	23.7	262	43.8	275	71.7	284	107	284	107	
L	2.4	"	"	"	"	271	25.4	280	46.8	293	76.5	302	113.5	302	113.5	
M	2.6	"	"	"	"	289	27.2	298	49.8	311	81.2	320	120.5	320	120.5	
N	2.8	"	"	"	"	307	28.8	316	52.8	329	86	339	127.2	339	127.2	
O	3.0	"	"	"	"	325	30.5	334	55.8	348	90.8	357	134	357	134	
P	3.25	.55	.6	.65	.7	348	32.7	357	59.6	370	96.6	380	142.7	380	142.7	
Q	3.5	"	"	"	"	371	34.9	380	63.5	393	102.6	402	151	402	151	
R	3.7	"	"	"	"	393	37	403	67.3	415	108.2	425	160	425	160	
S	4.05	"	"	"	"	416	39	425	71	438	114.3	448	168.5	448	168.5	
T	4.2	"	"	"	"	...	...	448	74.8	461	120.4	471	177	471	177	
U	4.55	"	"	"	"	...	...	470	78.5	484	126	493	185.3	493	185.3	
V	4.7	"	"	"	"	...	...	493	82.5	507	132	516	194	516	194	
W	5.05	"	"	"	"	...	...	516	86.2	529	138	539	203	539	203	
X	5.5	"	.85	.9	.95	...	...	562	94	575	150	584	220	584	220	
Y	6.0	"	"	"	"	...	...	607	101	620	162	630	237	630	237	

Material.—125 in. has been allowed for "parting off," and 6 in. waste on each 6 ft. bar of steel.
L=length, W=weight per 1,000.

D.E.P.A. (Detachable Data) System

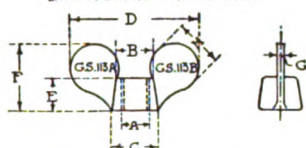
R. Horlase Mathew's Patents (practically protected) U.S. Patents applied for.

Bolts, Studs, Nuts, and Rivets—Continued

STANDARD WING NUTS

WING NUTS.

B.A. & B.S.F. WING NUTS



Specification.—*Material*—gun-metal stampings, R.A.F. Specification No. 22. *Part*, A.G.S. 113 for B.A. threads, and A.G.S. 120 for B.S.F. threads. Limits on dimensions B to H are $\pm .020$ in.

B.A. THREAD, A.G.S. 113

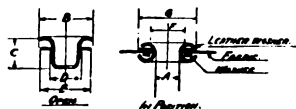
Mark.	Dimensions.							
	A.	B.	C.	D.	E.	F.	G.	H.
A	6 B.A.	In. ·25	In. ·280	In. 1·0	In. ·187	In. ·50	In. ·062	In. ·344
B	4 „	·25	·280	1·0	·187	·50	·062	·344
C	2 „	·312	·340	1·25	·25	·625	·062	·406

B.S.F. THREAD, A.G.S. 120

Mark.	Dimensions.							
	A.	B.	C.	D.	E.	F.	G.	H.
A	In. $\frac{1}{4}$	In. ·375	In. ·44	In. 1·50	In. ·31	In. ·75	In. $\frac{3}{32}$	In. ·50
B	$\frac{9}{32}$	·437	·52	1·62	·39	·812	$\frac{3}{32}$	·562
C	$\frac{11}{32}$	·437	·52	1·62	·39	·812	$\frac{3}{32}$	·562
D	$\frac{11}{32}$	·50	·60	1·75	·47	·875	$\frac{3}{32}$	·594
E	$\frac{8}{8}$	·50	·60	1·75	·47	·875	$\frac{3}{32}$	·594
F	$\frac{13}{32}$	·562	·71	2·0	·55	1·00	$\frac{1}{8}$	·687
G	$\frac{13}{32}$	·562	·71	2·0	·55	1·00	$\frac{1}{8}$	·687
H	$\frac{1}{2}$	·625	·82	2·25	·63	1·125	$\frac{1}{8}$	·75

EYELETS (A.G.S. 232)

Eyebles and their metal washers, sizes 1, 1A, 2, and 3, are made of commercial soft brass sheet, coated with stove Japan enamel, or, if unobtainable, black paint. Sizes 10 and 11 are made of commercial aluminium sheet.



EYELETS.

Size.	Brass.				Aluminium.	
	1	1A	2	3	10	11
EYE—	In.	In.	In.	In.	In.	In.
Diameter, A	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$
Depth, B	$\cdot 34$	$\cdot 38$	$\cdot 55$	$\cdot 6$	$\cdot 43$	$\cdot 55$
Thickness, C	$\cdot 12$	$\cdot 18$	$\cdot 24$	$\cdot 3$	$\cdot 26$	$\cdot 32$
Thickness of metal	$\cdot 012$	$\cdot 014$	$\cdot 014$	$\cdot 014$	$\cdot 014$	$\cdot 014$
WASHER—						
Diameter, D	$\cdot 20$	$\cdot 24$	$\cdot 30$	$\cdot 35$	$\cdot 24$	$\cdot 30$
Thickness, E	$\cdot 34$	$\cdot 38$	$\cdot 55$	$\cdot 6$	$\cdot 43$	$\cdot 55$
Thickness of metal	$\cdot 012$	$\cdot 012$	$\cdot 012$	$\cdot 012$	$\cdot 014$	$\cdot 014$
LEATHER WASHER—						
Diameter, F	$\cdot 2$	$\cdot 24$	$\cdot 3$	$\cdot 35$	$\cdot 24$	$\cdot 3$
Thickness of leather	$\cdot 38$	$\cdot 44$	$\cdot 6$	$\cdot 66$	$\cdot 5$	$\cdot 6$

STANDARD AIRCRAFT RIVETS

Duralumin Snap-head Rivets.—Material to Specification L.1. Part, A.G.S. 259, 16 ton duralumin. Dimensions, thickness of head = 0.75 diameter of shank; diameter of head = 2.3 diameter of shank.

Steel Countersunk Head Rivets.—Material to Specification S.21. Part, A.G.S. 261, 18 ton steel. Dimensions, thickness of head = 0.4 diameter of shank; diameter of head = 1.6 diameter of shank.

Standard sizes used of the above rivets:—

Diameters: $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1 , $1\frac{1}{2}$, 2 in., by the following lengths:—

Length: $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1 , $1\frac{1}{2}$, 2 in.

HIGH TENSILE STEEL WIRE (Specification W1)

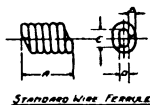
(V.) Wires, Wire Ropes, and Streamline Wires 621.88

Standard Wire Gauge.	Diameter.		Sectional Area, Square Inches.	Weight of 100 Feet.	Stress in Tons per Square Inch required by B. E. A. Specification.		Ultimate Strength on Wire in Lbs.	Ultimate Strength in Lbs. allowing for 65 per Cent. Joint Efficiency.	Number of Bends through 180°
	Inches.	Millimetres.			Min.	Max.			
6	.192	4.9	.029	9.81	...	...	5,500	3,600	...
7	.176	4.5	.024	8.26	...	...	4,550	2,950	...
8	.160	4.1	.020	6.82	80	90	3,800	2,470	3
9	.144	3.7	.0163	5.53	80	90	3,100	2,020	3
10	.128	3.3	.0129	4.37	85	95	2,600	1,700	3½
11	.116	3.0	.0106	3.60	90	100	2,250	1,460	4
12	.104	2.6	.0085	2.28	90	105	1,800	1,170	5
13	...	...	...	...	90	110	...	...	6
14	.080	2.0	.0050	1.70	95	115	1,180	770	7
15	...	...	...	...	95	115	...	...	10
16	.064	1.6	.0032	1.10	100	120	790	510	14
17	...	...	...	...	100	120	...	...	17
18	.048	1.2	.00181	.61	100	120	465	300	20
19	...	...	...	...	100	120	...	...	24
20	.036	.9	.00102	.34	...	...	...	...	...
22	.024	.7	.00062	.21	...	...	...	...	...
24	.022	.6	.00038	.13	...	...	...	...	...

Torsion Test.—20 turns per length of 100 d (where d = diameter in inches).

STANDARD WIRE FERRULE

Specification.—*Material*, W.1, tinned.
A.G.S. 156.



Mark.	Dimensions.				To Suit Standard Wire Gauge.
	A.	B.	C.	D.	
	In.	Gauge.	In.	In.	
A	.5	17	.100	.055	18
B	.55	16	.135	.070	16
C	.6	15	.165	.085	14
D	.7	14	.215	.110	12
E	.8	12	.265	.135	10
F	.85	11	.330	.165	8
Limits	±.10	...	+ .01 - .0	+ .01 - .0	...

FLEXIBLE STEEL WIRE ROPE

Ropes are preferable to stay rods because of their inherent flexibility. Moreover, they withstand shock or strain more readily, and if a strand should be cut it is not likely to damage more than two or three wires, the others remaining perfectly intact. Stay rods, on the other hand, deteriorate much more quickly, and are not nearly so elastic. They also require chains at the pulleys when working over pulley-blocks, which, of course, are not needed in the case of wire ropes and strands.

Specifications.—2W.2 for ropes other than for kite balloon work; W.6 for naval, and W.7 for R.A.F. kite balloon cables. In no case is more than one joint to occur in a length of 5 fathoms of strand. Specified weights may be exceeded by not more than 5 per cent. A tolerance of ± 0.0005 in. is permitted on the size of single wires in naval cables. In the case of R.A.F. cables there is a tolerance of ± 0.001 in. on the diameter, but not more than half the wires are to be below the nominal diameter. All wires are tinned, or otherwise protected from rusting.

Tests.—*Tensile.*—The ultimate strength must not exceed 135 tons per sq. in. for ordinary wire rope; or 150 tons per sq. in. for R.A.F. kite balloons; or 160 tons per sq. in. for naval cable. It must also be not less than that specified by the manufacturer, or in the case of naval cable, not less than 150 tons per sq. in.

Torsion.—The wire must stand 27.5 turns per length of 100 times the diameter, for all wires up to and including 0.018 in.

Wires, Wire Ropes, and Streamline Wires—Continued 621.88

diameter, and 20 turns for bigger wires. The R.A.F. kite balloon cables must withstand 26 turns. Sample must be bent once round its own part and straightened again, at least 20 times in succession without any of the wires breaking, or the rope opening up. Ropes with telephone cores are tested also for insulation and conductivity.

Wire Ropes.—The following list comprises the most usual wire ropes employed for connecting up flying controls, etc. :—

A single strand of 19 wires.

12 strands, 9 over 3, of 3 wires each.

7 " 6 " 1, " 7 "
7 " 6 " 1, " 19 "

FLEXIBLE STEEL WIRE ROPE

Minimum Breaking Strength.	Maximum Diameter.	Construction.	Weight of 100 Ft.
EXTRA FLEXIBLE ROPES			
Cwt.	In.		Lbs.
5	·075	4 × 7	1·0
10	·115	4 × 19	2·0
15	·137	"	3·2
20	·150	7 × 19	3·8
25	·168	7 × 19	5·0
35	·195	"	6·4
45	·228	"	9·0
60	·262	"	11·7
70	·270	"	12·4
80	·305	"	15·1
100	·349	"	19·6
120	·378	7 × 27	22·5
140	·388	"	25·5
160	·418	7 × 37	28·9
STANDARD STRAINING CORDS			
10	·085	1 × 19	1·6
15	·105	"	2·3
20	·125	"	3·4
25	·143	"	4·3
35	·161	1 × 37	5·5
45	·189	"	7·5
60	·210	"	9·3
75	·238	"	11·9
90	·259	"	14·1

Wires, Wire Ropes, and Streamline Wires—Continued

NAVAL KITE BALLOON CABLES

Minimum Breaking Load of Cable.	Maximum Diameter of Cable.	Construction.	Diameter of Wire.	Lay of		Weight of 1,000 Ft. of Cable.
				Wires in Strand.	Strand in Rope.	
EXTRA FLEXIBLE ROPES WITH WIRE CORE						
Cwt.	In.		In.	In.	In.	Lbs.
126	340	7 × 19	0218	1-3	2-6	182
129	343	"	0220	1-3	2-6	183
141	358	"	0230	1-4	2-75	202
153	374	"	0240	1-4	2-9	220
166	390	"	0250	1-5	3-0	239
EXTRA FLEXIBLE ROPES WITH TELEPHONE OR HEMP CORE						
108	340	6 × 19	0218	1-25	2-6	167
110	343	"	0220	1-25	2-6	170
120	358	"	0230	1-375	2-75	186
131	374	"	0240	1-375	2-9	202
143	390	"	0250	1-50	3-0	220

R.A.F. KITE BALLOON CABLES

Minimum Breaking Load.	Maximum Diameter.	Construction.	Lay of		Maximum Weight per Fathom.
			Wires in Strand.	Strand in Rope.	
Lbs. 7,280 (3.25 tons)	Mm. 6.8	6 × 19 (with jute core)	In. 1½	In. 2½	Lb. 0.65
4,480 (2.0 tons)	5.5	6 × 19 (with jute core)	1	1½	0.45

Wires, Wire Ropes, and Streamline Wires—*Continued*

FLEXIBLE STRANDED STEEL WIRE CABLE

(Cradock)

Minimum Breaking Strength.	Maximum Circumference in Inches.	Maximum Diameter in Inches.	Construction.	Weight per 10 Ft.
5 cwt.	0.213	0.068	7 × 7 × 0.0076 in.	...
10 "	0.345	0.110	7 × 14 × 0.0084 "	...
15 "	0.445	0.142	7 × 19 × 0.0092 "	5 oz.
20 "	0.508	0.162	7 × 19 × 0.010 "	6 "
25 "	0.560	0.177	7 × 19 × 0.011 "	8 "
30 "	0.607	0.193	7 × 19 × 0.012 "	9 "
35 "	0.630	0.201	7 × 19 × 0.013 "	10 "
40 "	0.669	0.213	7 × 19 × 0.014 "	12½ "
45 "	0.728	0.232	7 × 19 × 0.015 "	14 "
50 "	0.756	0.241	7 × 19 × 0.016 "	1 lb.
60 "	0.827	0.264	7 × 19 × 0.017 "	1 lb. 2 oz.
70 "	0.854	0.272	7 × 19 × 0.018 "	1.25 lbs.
75 "	0.906	0.289	7 × 19 × 0.019 "	1.35 "
80 "	1.016	0.323	7 × 19 × 0.020 "	...
85 "	1.031	0.328	7 × 19 × 0.021 "	1.58 "
95 "	1.062	0.338	7 × 19 × 0.022 "	1.8 "
5 tons	1.094	0.349	7 × 19 × 0.023 "	1.96 "
5½ "	1.156	0.368	7 × 19 × 0.024 "	2.13 "
6 "	1.1875	0.378	7 × 27 × 0.021 "	2.25 "
7 "	1.219	0.388	7 × 27 × 0.022 "	2.55 "
7½ "	1.25	0.398	7 × 37 × 0.019 "	2.63 "
8 "	1.3125	0.418	7 × 37 × 0.020 "	2.89 "
9 "	1.375	0.437	7 × 37 × 0.021 "	3.08 "
10 "	1.437	0.457	7 × 37 × 0.022 "	3.49 "
11 "	1.5	0.478	7 × 37 × 0.023 "	3.81 "
12 "	1.594	0.508	7 × 37 × 0.024 "	4.15 "

In the above table, in the column dealing with construction, the number of strands is seven, the second figure is the number of wires per strand, while the last figure is the diameter of each individual wire.

Wires, Wire Ropes, and Streamline Wires—Continued**STREAMLINE WIRES AND SWAGED WIRES****Part I. Steel Rod****Specifications, 2W.3 and 2W.8****Chemical Analysis—**

Carbon	-	-	Between 0.40 and 0.52 per cent.
Manganese	-	-	" 0.50 and 0.90 "
Silicon	-	-	Not more than 0.3 per cent.
Sulphur	-	-	" " 0.04 "
Phosphorus	-	-	" " 0.04 "

For steel rods of $\frac{1}{8}$ in. diameter to $\frac{1}{2}$ in. diameter, the upper limit of carbon may be increased to 0.57 per cent. for streamline wires.

Size—

Diameter of Rod.	Limits.
Up to and including $\frac{1}{8}$ in.	$\left\{ \begin{array}{l} - 0 \\ + .002 \end{array} \right.$
From $\frac{1}{8}$ in. to $\frac{1}{4}$ in.	$\left\{ \begin{array}{l} - 0 \\ + .003 \end{array} \right.$
From $\frac{1}{4}$ in. to $\frac{1}{2}$ in.	$\left\{ \begin{array}{l} - 0 \\ + .004 \end{array} \right.$

Mechanical Tests—**(a) Tensile:**

Diameter of Steel Rod.	Ultimate Tensile Stress.		
	* Tons per Sq. In.	Lbs. per Sq. In.	Kgs. per Sq. Mm.
No. 4 B.A. to $\frac{1}{8}$ in., inclusive	55-65	123,200-145,600	86.6-102.4
$\frac{1}{8}$ in. to $\frac{1}{2}$ in., inclusive	52-62	116,480-138,880	81.9-97.6

* 1 ton = 2,240 lbs.

(b) Bend Test—

For Steel Rod under $\frac{1}{8}$ in. Diameter.—The sample is fixed in a vice, or between dies, of which the inner edges are rounded to a

Wires, Wire Ropes, and Streamline Wires—Continued

radius equal to three times the diameter of the wire. The projecting end is then bent at right angles to the fixed part, and afterwards bent backwards and forwards through an angle of 180° , till it shows signs of fracture. The steel rod should stand, without showing signs of fracture, the following number of bends through 180° (the first bend through 90° is not counted).

Diameter of Steel Rod.	Minimum Number of Bends.
4 B.A. and 2 B.A. - -	6
$\frac{7}{32}$, $\frac{1}{4}$, $\frac{3}{32}$, and $\frac{1}{16}$ in. - -	5
$\frac{1}{8}$, $\frac{3}{16}$, and $\frac{1}{4}$ in. - -	4
$\frac{1}{16}$ and under $\frac{1}{16}$ in. - -	3

For Steel Rods $\frac{1}{16}$ in. and $\frac{1}{8}$ in. Diameter.—The sample should stand bending through an angle of 180° without showing signs of fracture, the internal radius of the bend being equal to the diameter of the wire.

Part II. Blanks for Streamline Wires and Swaged Wires**Dimensions, Shapes, and Tolerances for 2W.3 Specification.**

—The cross-sectional area of the oval portion of the wire should not be less than the minimum given in the table, and should not exceed it by more than the following amount:—

Diameter of Wire Rod.	Amount by which the Cross-Sectional Area may be Exceeded.
No. 4 B.A. - -	20 per cent.
" 2 " - -	$12\frac{1}{2}$ "
$\frac{7}{32}$ in. - -	10 "
$\frac{1}{4}$ in. to $\frac{1}{2}$ in. - -	$7\frac{1}{2}$ "

The sectional area may be assumed to be $0.769 W \times T$ where W and T are the diameters of the oval, or it may be ascertained by weighing a length of the wire. The weight per foot run of the wire of 0.1 sq. in. section may be taken as 0.34 lb.

Wires, Wire Ropes, and Streamline Wires—Continued**Tests.**—Tensile tests of screwed end and oval * portion :—

A test sample cut from one end of each blank selected for testing should have the round end screwed in a pair of screwing dies, so that it is a good fit in an approved gauge :—

The screwed end should be fitted with a forked end, or with a nut, by which the load can be applied. The wire should be gripped at the oval * end, so that the round part, the shoulder and the oval * portion are included in the part under stress. Under this condition of tensile loading, the wire should break in the oval * portion, and should show an ultimate strength not less than the value given in the following tables.

The screwed portion should then be fitted with nuts or forked ends, and subjected to a tensile test in order to determine the strength of the screw. The ultimate load should not be less than that obtained from the oval or swaged section.

(This condition does not necessarily apply to the No. 4 B.A. wire.)

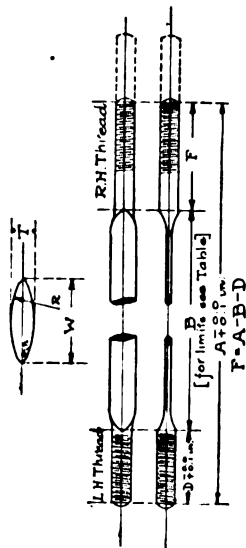
Bend Test—

For Blanks under $\frac{1}{8}$ in. Diameter.—One of the samples should be cut from the end of the blank, so as to include the shoulder, and the test should be applied, so that the sample is bent in the oval * portion near the shoulder ; the sample being held by the oval * part at a distance of about four times the diameter of the screw from the shoulder. The other sample should be bent in the oval * part away from the shoulder. The sample should be fixed in a vice which has the inner edges of the jaws rounded to a radius equal to three times the thickness of the wire given in the table. The projecting end of the wire should then be bent at right angles to the fixed part, first to one side and then to the other, for a number of times, until it shows signs of fracture. Both samples should stand without showing signs of fracture, the number of bends specified under "Mechanical Bend Tests," each through 180°. The first bend through 90° should not be counted.

For Blanks $\frac{1}{4}$ in. and $\frac{1}{2}$ in. Diameter.—The sample should withstand bending through an angle of 180° without showing signs of cracks or flaws, the internal radius of the bend being equal to the thickness of the wire.

* For Specification 2W.8, read "swaged."

Crosby Lockwood & Sons' TECHNICAL DATA SERIES.



STREAMLINE WIRES

(Specification 2 W. 3)

Note.—Length of thread (max.) = $D - 0.1$ in.
 " " (min.) = $D - 0.25$ in.

Minimum Tensile Strength.	Threads, R. and L. Hand.			Oval Portion of Wire.				Area.	
	Diameter.	Area at Bottom of Thread.	D. Length.	W. Min.	T. Min.	R.	r.	Min.	Max.
Lbs	In.	Sq. In.	In.	In.	In.	In.	In.	Sq. In.	Sq. In.
1,050	4 B. A.	0.0096	1.5	0.192	0.048	0.288	0.011	0.0071	0.0085
1,900	2 "	0.0169	1.6	0.256	0.064	0.384	0.014	0.0126	0.0142
2,600	3/4 B. S. F.	0.0235	1.8	0.301	0.075	0.451	0.017	0.0174	0.0191
3,450	1/2 "	0.0316	1.8	0.348	0.087	0.522	0.019	0.0233	0.0250
4,650	3/8 "	0.0423	1.9	0.404	0.101	0.606	0.022	0.0314	0.0338
5,700	1/4 "	0.0508	2.0	0.44	0.11	0.66	0.024	0.0372	0.04
7,150	3/16 "	0.0640	2.1	0.496	0.124	0.744	0.027	0.0473	0.0508
8,500	1/8 "	0.0760	2.2	0.54	0.135	0.81	0.03	0.05610	0.0603
10,250	3/32 "	0.0920	2.3	0.596	0.149	0.894	0.033	0.0683	0.0734
11,800	1/16 "	0.1054	2.4	0.636	0.159	0.954	0.035	0.0778	0.0836
13,800	3/64 "	0.1242	2.5	0.692	0.173	1.038	0.038	0.0921	0.099
15,500	1/32 "	0.1385	2.5	0.732	0.183	1.098	0.04	0.1030	0.1107
20,200	1/16 "	0.1828	3.1	0.836	0.209	1.254	0.045	0.1344	0.1445
24,700	3/16 "	0.2235	3.4	0.924	0.231	1.386	0.05	0.1641	0.1764

STREAMLINE WIRES—Continued
(Specification 2W.3)

Fittings—A.G.S. Nos.									
Diameter.	Fork Ends, R. and L.H.	Lock Nuts, Spec. 2A.1		Universal Joints with Trunnions and Lock Nuts.	Width of Gap in Fork.	Dia. of Pin Hole in Fork.	Pins for Forks.	Split Pins, 166.	In. Dia. Length.
		R.H.	L.H.							Mark.
In. 4 B.A.	412	115	238	451	In. 0.1	In. $\frac{1}{16}$	383/2		In. $\frac{1}{16}$ x $\frac{1}{4}$
2 "	413	"	"	452	0.15	$\frac{1}{16}$	19		x $\frac{1}{4}$ x $\frac{1}{4}$
3 " B.S.F.	411	"	"	450	"	"	37		x $\frac{1}{8}$ x $\frac{1}{8}$
4 "	414	117	239	453	0.2	$\frac{1}{8}$	54		x $\frac{1}{8}$ x $\frac{1}{8}$
5 "	415	"	"	454	0.2	$\frac{1}{8}$	72		x $\frac{1}{8}$ x $\frac{1}{8}$
6 "	416	"	"	455	0.25	$\frac{1}{4}$	106		x $\frac{3}{16}$ x $\frac{3}{16}$
7 "	417	"	"	456	0.25	$\frac{1}{4}$	107		x $\frac{3}{16}$ x $\frac{3}{16}$
8 "	418	"	"	457	0.3	$\frac{1}{2}$	140		x $\frac{1}{2}$ x $\frac{1}{2}$
9 "	419	"	"	458	0.34	$\frac{1}{2}$	156		x $\frac{1}{2}$ x $\frac{1}{2}$
10 "	420	"	"	459	0.36	$\frac{1}{2}$	173		x $\frac{1}{2}$ x $\frac{1}{2}$
11 "	421	"	"	460	0.38	$\frac{1}{2}$	191		x $\frac{1}{2}$ x $\frac{1}{2}$
12 "	422	"	"	461	0.4	$\frac{1}{2}$	208		x $\frac{1}{2}$ x $\frac{1}{2}$
...	...	"	"	...	...	...	...		...
14 "	...	"	"	...	...	...	...		...

DE-DA (Detachable Data) System
R. Burlase Mattheus' Patents (provisionally protected). U.S. Patents applied for.

TYPICAL SCHEDULE FOR STREAMLINE WIRES

(For particulars of other sizes, see table, pp. 249-50)

Size, 2BA.

Ultimate strength: 1,900 lbs.

Thread: 2 B.A. D. = 1.6 in.

 $1.6 \begin{smallmatrix} -0 \\ +0.1 \end{smallmatrix}$ in.Oval: W = 0.256 in. (min.); T = 0.064 in. (min.); R = 0.384 in.;
r = 0.014 in.

Area of oval = 0.0126 sq. in. (min.); 0.0142 sq. in. (max.).

Cross-sectional area at bottom of thread = 0.0169 sq. in. (approx.).

Crosby Lockwood & Sons' TECHNICAL DATA SERIES.

Part No.	B (with Limits).	Overall Length for Blanks.	For "A" Lengths between		Part No.	B (with Limits).	Overall Length for Blanks.	For "A" Lengths between	
			Min.	Max.				Min.	Max.
	In.	In.	In.	In.		In.	In.	In.	In.
1	3.5	10.5	7	10.5	28	111.5	118.5	115	118.5
2	7.5	14.5	11	14.5	29	115.5	122.5	119	122.5
3	11.5	18.5	15	18.5	30	119.5	126.5	123	126.5
4	15.5	22.5	19	22.5	31	123.5	130.5	127	130.5
5	19.5	26.5	23	26.5	32	127.5	134.5	131	134.5
6	23.5	30.5	27	30.5	33	131.5	138.5	135	138.5
7	27.5	34.5	31	34.5	34	135.5	142.5	139	142.5
8	31.5	38.5	35	38.5	35	139.5	146.5	143	146.5
9	35.5	42.5	39	42.5	36	143.5	150.5	147	150.5
10	39.5	46.5	43	46.5	37	147.5	154.5	151	154.5
11	43.5	50.5	47	50.5	38	151.5	158.5	155	158.5
12	47.5	54.5	51	54.5	39	155.5	162.5	159	162.5
13	51.5	58.5	55	58.5	40	159.5	166.5	163	166.5
14	55.5	62.5	59	62.5	41	163.5	170.5	167	170.5
15	59.5	66.5	63	66.5	42	167.5	174.5	171	174.5
16	63.5	70.5	67	70.5	43	171.5	178.5	175	178.5
17	67.5	74.5	71	74.5	44	175.5	182.5	179	182.5
18	71.5	78.5	75	78.5	45	179.5	186.5	183	186.5
19	75.5	82.5	79	82.5	46	183.5	190.5	187	190.5
20	79.5	86.5	83	86.5	47	187.5	194.5	191	194.5
21	83.5	90.5	87	90.5	48	191.5	198.5	195	198.5
22	87.5	94.5	91	94.5	49	195.5	202.5	199	202.5
23	91.5	98.5	95	98.5	50	199.5	206.5	203	206.5
24	95.5	102.5	99	102.5	51	203.5	210.5	207	210.5
25	99.5	106.5	103	106.5	52	207.5	214.5	211	214.5
26	103.5	110.5	107	110.5	53	211.5	218.5	215	218.5
27	107.5	114.5	111	114.5	54	215.5	222.5	219	222.5

Note.—The "Part Nos.," "B" lengths, and "limits" are the same for all diameters of wire, but the "overall" lengths vary with the dimensions of the end fittings.

For meaning of letters in above table refer to diagram on p. 249.

SWAGED WIRES—(Specification 2W.8)

Minimum Tensile Strength.	Threads, R. and L. Hand.			Swaged Part.		Square Part.		D Length. -0 +0.1 In.
	Diameter.	Length. C +0.15 In.	Area of Bottom of Thread.	Diameter.	Area.	Length. H - 0.0 + 0.1 In.	Width Across Flat, ± .002 In.	
Lbs.	In.	In.	Sq. In.	In.	Sq. In.	In.	In.	In.
1,050	4	B.A.	1.1	0.0096	0.104 -0 +0.006	0.0085	0.16	1.5
1,900	2	"	1.1	0.0169	0.128 -0 +0.006	0.0129	0.20	1.6
2,600	3/4	B.S.F.	1.2	0.0235	0.149 -0 +0.006	0.0174	0.20	1.7
3,450	1/2	"	1.3	0.0316	0.171 -0 +0.007	0.023	0.20	1.8
4,650	9/32	"	1.4	0.0423	0.207 -0 +0.008	0.0337	0.26	1.9
5,700	1/8	"	1.5	0.0508	0.223 -0 +0.009	0.0391	0.26	2.0
7,150	3/16	"	1.5	0.0640	0.251 -0 +0.009	0.0495	0.32	2.1
8,500	3/8	"	1.6	0.0760	0.274 -0 +0.010	0.059	0.32	2.2
10,250	1/2	"	1.6	0.0920	0.303 -0 +0.011	0.0721	0.38	2.3
11,800	5/8	"	1.7	0.1054	0.326 -0 +0.012	0.0835	0.38	2.4
13,800	3/4	"	1.8	0.1242	0.355 -0 +0.013	0.0989	0.45	2.4
15,500	1	"	1.9	0.1385	0.377 -0 +0.014	0.1116	0.45	2.5

Wires, Wire Ropes, and Streamline Wires—Continued 621.88



SWAGED WIRES—Continued
(Specification 2W.8)

Fittings—A.G.S. Nos.

Diameter.	Fork Ends, R. and L.H.	Lock Nuts. Spec. 2A.1.		Pins for Forks, 883.	Split Pins, 168.		Width of Gap in Fork.	Dia. of Pin Hole in Fork.
		R.H.	L.H.		Diameter.	Length.		
In.	412	115	238	Pt. 2	In. $\frac{1}{16}$	In. $\frac{1}{4}$	In. $\frac{3}{8}$	In. $\frac{3}{8}$
B.A. 2	413	"	"	19	In. $\frac{1}{16}$	"	0.15	In. $\frac{1}{8}$
"	411	117	"	37	In. $\frac{1}{16}$	"	"	"
B.S.F. 7	414	"	239	54	In. $\frac{3}{32}$	"	0.2	"
" 1	415	"	"	72	In. $\frac{3}{32}$	"	"	"
" 1	416	"	"	106	In. $\frac{3}{32}$	"	0.25	"
" 1	417	"	"	107	In. $\frac{3}{32}$	"	"	"
" 1	418	"	"	140	In. $\frac{1}{8}$	"	0.3	"
" 1	419	"	"	156	In. $\frac{1}{8}$	"	0.34	"
" 1	420	"	"	173	In. $\frac{1}{8}$	"	0.36	"
" 1	421	"	"	191	In. $\frac{1}{8}$	"	0.38	"
" 1	422	"	"	208	In. $\frac{1}{8}$	"	0.4	In. $\frac{1}{2}$

TYPICAL SCHEDULE FOR SWAGED WIRES

(For particulars of other sizes, see table, pp. 252-3)

SIZE, $\frac{1}{4}$ IN.

Ultimate strength : 3,450 lbs.

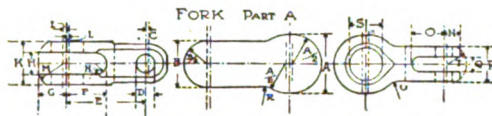
Thread, $\frac{1}{4}$ in. B.S.F. : $D=1.8$ in. ; $H=0.20$ $\begin{cases} -0. \\ +0.1 \text{ in.} \end{cases}$; $C=1.3$ $\begin{cases} -0. \\ +0.15 \text{ in.} \end{cases}$ Width across flats of square $=0.19 \pm .002$ in.Diameter of swaged part $=0.171$ $\begin{cases} -0. \\ +0.007 \text{ in.} \end{cases}$ Area of swaged part $=0.023$ sq. in.

Part. No.	B (with Limits).	Overall Length for Blanks.	For "A" Lengths Between		Part. No.	B (with Limits).	Overall Length for Blanks.	For "A" Lengths Between	
			Min.	Max.				Min.	Max.
	In.		In.	In.		In.		In.	In.
2	6 $\begin{cases} + .0 \\ - .25 \end{cases}$	15.5	10	15.5	18	180 $\begin{cases} + .0 \\ - 1.75 \end{cases}$	195.5	184	195.5
3	12 $\begin{cases} + .0 \\ - .25 \end{cases}$	21.5	16	21.5	19	192 $\begin{cases} + .0 \\ - 1.75 \end{cases}$	207.5	196	207.5
4	18 $\begin{cases} + .0 \\ - .5 \end{cases}$	27.5	22	27.5	20	204 $\begin{cases} + .0 \\ - 2.0 \end{cases}$	219.5	208	219.5
5	24 $\begin{cases} + .0 \\ - .5 \end{cases}$	39.5	28	39.5	21	216 $\begin{cases} + .0 \\ - 2.0 \end{cases}$	231.5	220	231.5
6	36 $\begin{cases} + .0 \\ - .5 \end{cases}$	51.5	40	51.5	22	228 $\begin{cases} + .0 \\ - 2.0 \end{cases}$	243.5	232	243.5
7	48 $\begin{cases} + .0 \\ - .75 \end{cases}$	63.5	52	63.5	23	240 $\begin{cases} + .0 \\ - 2.0 \end{cases}$	255.5	244	255.5
8	60 $\begin{cases} + .0 \\ - .75 \end{cases}$	75.5	64	75.5	24	252 $\begin{cases} + .0 \\ - 2.0 \end{cases}$	267.5	256	267.5
9	72 $\begin{cases} + .0 \\ - 1.0 \end{cases}$	87.5	76	87.5	25	264 $\begin{cases} + .0 \\ - 2.0 \end{cases}$	279.5	268	279.5
10	84 $\begin{cases} + .0 \\ - 1.0 \end{cases}$	99.5	88	99.5	26	276 $\begin{cases} + .0 \\ - 2.0 \end{cases}$	291.5	280	291.5
11	96 $\begin{cases} + .0 \\ - 1.25 \end{cases}$	111.5	100	111.5	27	288 $\begin{cases} + .0 \\ - 2.0 \end{cases}$	303.5	292	303.5
12	108 $\begin{cases} + .0 \\ - 1.25 \end{cases}$	123.5	112	123.5	28	300 $\begin{cases} + .0 \\ - 2.0 \end{cases}$	315.5	316	315.5
13	120 $\begin{cases} + .0 \\ - 1.25 \end{cases}$	135.5	124	135.5	29	312 $\begin{cases} + .0 \\ - 2.0 \end{cases}$	327.5	328	327.5
14	132 $\begin{cases} + .0 \\ - 1.50 \end{cases}$	147.5	136	147.5	30	324 $\begin{cases} + .0 \\ - 2.0 \end{cases}$	339.5	328	339.5
15	144 $\begin{cases} + .0 \\ - 1.50 \end{cases}$	159.5	148	159.5	31	336 $\begin{cases} + .0 \\ - 2.0 \end{cases}$	351.5	340	351.5
16	156 $\begin{cases} + .0 \\ - 1.50 \end{cases}$	171.5	160	171.5	32	348 $\begin{cases} + .0 \\ - 2.0 \end{cases}$	363.5	352	363.5
17	168 $\begin{cases} + .0 \\ - 1.75 \end{cases}$	183.5	172	183.5					

Note.—The "Part Nos.," "B" lengths, and "limits" are the same for all diameters of wire, but the "overall" lengths vary with the dimensions of the end fittings.
For meaning of letters in above table refer to diagram on p. 253.

(VI.) Fork Ends, Turnbuckles, Shackles, Etc.

STANDARD FORK JOINT



Specification.—*Material*—S.1 (Part 1), 35 tons mild steel. *Part*, Nos. 411-422. Right-hand joints are known as “Mark A,” and left-hand as “Mark B.” The former standards made of high tension steel, A.G.S. 168-178, should no longer be used. The following sizes have been renumbered :—

No. 1,168	-	-	Thread 4 B.A.,	renumbered 412.
„ 1,169	-	-	„ 2 B.A.,	„ 413.
„ 1,170	-	-	„ ½ in. B.S.F.,	„ 414.

NEW TYPE MADE FROM M.S. TO SPECIFICATION S.1, PART 1.

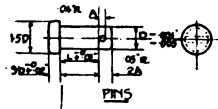
NEW TYPE MADE FROM M.S. TO SPECIFICATION S.1, PART 1.													
Old Type Made of H.Y. Steel.	A.G.S. No.	Dia. of Thread.	Minimum Tensile Strength.	A.G.S. No.	Dia. of Thread.	Fork.			Pin.	Split Pin.	Length.	Dia.	Weight.
						Gap.	Dia. of Pin Hole.	Overall Width.					
		In.				In.							
		B.A.				In.							
		4				$\frac{3}{8}$							
		2				$\frac{1}{2}$							
		B.S.F.				$\frac{3}{4}$							
		1/8	1,050	412	4	.1	$\frac{3}{8}$	.26	2	$\frac{1}{2} \times \frac{1}{2}$	140	$\frac{3}{8}$	.47
		1/16	1,900	413	5	.15	$\frac{1}{2}$	.33	19	$\frac{1}{2} \times \frac{1}{2}$	164	$\frac{1}{2}$	.99
		...	2,600	411	5	.2	$\frac{3}{4}$	.42	37	$\frac{1}{2} \times \frac{1}{2}$	189	$\frac{1}{2}$	1.43
		B.S.F.	3,450	414	6.5	.2	$\frac{1}{2}$	.45	54	$\frac{1}{2} \times \frac{1}{2}$	187	$\frac{3}{8}$	1.7
		$\frac{3}{8}$	4,650	415	7	.2	$\frac{3}{4}$	.58	72	$\frac{3}{4} \times \frac{3}{4}$	210	$\frac{3}{4}$	2.8
		$\frac{1}{2}$	5,700	416	7.5	.25	$\frac{1}{2}$	.68	106	$\frac{3}{4} \times \frac{3}{4}$	227	$\frac{1}{2}$	4.2
		$\frac{5}{8}$	7,150	417	8	.25	$\frac{3}{4}$	.73	107	$\frac{3}{4} \times \frac{3}{4}$	231	$\frac{1}{2}$	4.8
		$\frac{3}{4}$	8,500	418	8.5	.3	$\frac{1}{2}$	.78	140	$\frac{3}{8} \times \frac{1}{2}$	255	$\frac{1}{2}$	6.1
		$\frac{1}{2}$	10,250	419	9	.34	$\frac{3}{4}$	.78	156	$\frac{1}{2} \times \frac{1}{2}$	285	$\frac{1}{2}$	7.7
		$\frac{3}{4}$	11,800	420	9.8	.36	$\frac{1}{2}$	.83	173	$\frac{1}{2} \times \frac{1}{2}$	298	$\frac{1}{2}$	10.1
		$\frac{1}{2}$	13,800	421	10.4	.38	$\frac{1}{2}$	.93	191	$\frac{1}{2} \times \frac{1}{2}$	316	$\frac{1}{2}$	11.8
		$\frac{3}{4}$	15,500	422	11.1	.4	$\frac{1}{2}$	.98	208	$\frac{1}{2} \times \frac{1}{2}$	384	$\frac{1}{2}$	14.3

Material Quantities.—0.25 in. allowed for "parting-off," and 6 in. waste on each 6 ft. bar of steel.

DE-DA (Detachable Data) System
R. R. Boring, Matheson, Patents (provisionally protected). U.S. Patents applied for.

Fork Ends, Turnbuckles, Shackles, Etc.—Continued

PINS



Specification.—*Material*—W.3, Part 1, 55 ton steel, 0.45 to 0.52 carbon. *Part*, A.G.S. 383.

Diameter, "D" -	In. $\frac{5}{8}$	In. $\frac{3}{4}$	In. $\frac{7}{8}$	In. 1	In. $1\frac{1}{8}$	In. $1\frac{1}{4}$	In. $1\frac{1}{2}$	In. $1\frac{3}{4}$	In. 2	In. $2\frac{1}{4}$	In. $2\frac{1}{2}$	In. $2\frac{3}{4}$	In. 3
Diameter of head	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{5}{8}$	2
Drill for "A" -	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	1	$1\frac{1}{8}$

Lengths, "L": .25, .30, .35, .40, .45, .50, .55, .60, .65, .70, .75, .80, .85, .90, and 1.0 in.

All diameters are made in all lengths.

All lengths are made in all diameters.

Specification.—*Material*—S.2, high tensile alloyed steel bar, 45 ton steel. *Part*, A.G.S. 384.

Diameter, "D" -	In. $\frac{5}{8}$	In. $\frac{3}{4}$	In. 1	In. $1\frac{1}{8}$	In. $1\frac{1}{4}$	In. $1\frac{1}{2}$	In. $1\frac{3}{4}$	In. 2	In. $2\frac{1}{4}$	In. $2\frac{1}{2}$	In. $2\frac{3}{4}$	In. 3
Drill for "A" -	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	1	$1\frac{1}{8}$

Lengths, "L": 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4 in.

All diameters are made in all lengths.

All lengths are made in all diameters.

STANDARD PINS FOR FORK ENDS, TURNBUCKLES, SHACKLES, ETC.

TABLE SHOWING CORRESPONDING SIZES IN OLD AND NEW STANDARDS

Old Type.			New Type.			Old Type.			New Type.		
A.G.S. No.	Dia.	Length, L.	A.G.S. No.	Dia.	Length, L.	A.G.S. No.	Dia.	Length, L.	A.G.S. No.	Dia.	Length, L.
137 A	In. $3\frac{5}{16}$	.247	383/1	In. $3\frac{5}{16}$	.25	137 I	In. $\frac{1}{2}$	.567	383/56	In. $\frac{1}{2}$	.60
B	" $3\frac{5}{16}$	.267	2	" $3\frac{5}{16}$	.30	L	" $\frac{3}{8}$	.607	56	" $\frac{3}{8}$	.60
C	" $1\frac{1}{8}$	.277	18	" $1\frac{1}{8}$	.30	J	" $\frac{3}{8}$	.482	70	" $\frac{3}{8}$	.50
D	" "	.367	24	" "	.40	K	" $\frac{1}{2}$	1.002	80	" $\frac{1}{2}$	1.0
E	" "	.327	19	" "	.35	M	" $\frac{1}{2}$	.602	104	" $\frac{1}{2}$	.60
F	" "	.647	25	" "	.65	P	" $\frac{1}{2}$	.667	138	" $\frac{1}{2}$	.70
G	" "	.792	28	" "	.80	R	" $1\frac{1}{8}$	.687	154	" $1\frac{1}{8}$	.75
O	" "	.367	20	" "	.40	T	" $\frac{1}{2}$	.737	171	" $\frac{1}{2}$	.80
S	" "	.417	21	" "	.45	V	" $\frac{1}{2}$	1.767	384/288	" $\frac{1}{2}$	.80
U	" "	.437	21	" "	.45	W	" $\frac{1}{2}$	.787	383/188	" $\frac{1}{2}$	.85
G	" $\frac{1}{2}$	.437	53	" $\frac{1}{2}$	.45	X	" $\frac{1}{2}$	.837	205	" $\frac{1}{2}$	
H	" "	.517	55	" "	.55						

Note.—Material to be steel to Specifications S.2 or W.3, Part 1.

The following sizes have been renumbered as shown :

1,137 A renumbered 383/1.

1,137 B " 383/19.

1,137 C " 383/53.

DE-DA (Detachable Data) System

R. P. Moore Mathematical Patent (provisionally protected). U.S. Patents applied for.

Fork Ends, Turnbuckles, Shackles, Etc.—*Continued*

TABLE SHOWING MATERIAL REQUIRED TO MAKE 1,000 PINS OF THE SIZES USED IN FORK ENDS

A.G.S. No.	Size.	Dia. of Head.	Overall Length.	Material per 1,000.		
				Length.	Dia.	Weight.
383/2	In. $\frac{5}{32}$	In. $\frac{1}{4}$	In. .472	Ft. 55	In. $\frac{1}{4}$	Lbs. 9
19	$\frac{3}{16}$	$\frac{5}{16}$	.531	61	$\frac{5}{16}$	16
54	$\frac{1}{2}$	$\frac{3}{4}$	.70	76	$\frac{3}{4}$	29
72	$\frac{9}{32}$	$\frac{3}{8}$	.871	91	$\frac{3}{8}$	34
106	$\frac{11}{32}$	$\frac{7}{16}$	.99	102	$\frac{7}{16}$	52
107	$\frac{11}{32}$	$\frac{7}{16}$	1.04	109	$\frac{7}{16}$	56
140	$\frac{13}{32}$	$\frac{7}{8}$	1.172	118	$\frac{7}{8}$	79
156	$\frac{7}{16}$	$\frac{1}{2}$	1.181	119	$\frac{1}{2}$	101
173	$\frac{15}{32}$	$\frac{1}{2}$	1.241	125	$\frac{1}{2}$	105
191	$\frac{1}{2}$	$\frac{5}{8}$	1.35	134	$\frac{5}{8}$	140
208	$\frac{17}{32}$	$\frac{3}{4}$	1.409	140	$\frac{3}{4}$	146

Note.—0.125 in. allowed for "parting-off," and 6 in. waste on each 6 ft. bar of steel.

AIRCRAFT TURNBUCKLES

Old Type with H.T. Steel Ends.		Minimum Tensile Strength		A.G.S. No.		Standard Turnbuckles.		Fork End.		Eye End.		Adjustment.		Material Required to Make 1,000 Pieces (Approximate).					
														Fork A.		Barrel B.		Eye C. or E.	
A.G.S. No.	Dia. of Thread.	Lbs.	In.	Cwt.	Known as	Dia. of Thread.	Gap.	Dia. of Pin Hole.	Overall Width.	Dia. of Hole.	In.	Pin Closed, Max.	Pin Closed, ABC Type.	Length.	Dia.	Weight.	Length.	Dia.	Weight.
138	6 B.A.	600	490	5	5	4 B.A.	18	5/32	18	11/64	8	2 1/2	146	11/32	173	0.75	128	9/32	0.75
139	6 "	600	491	10	10	2 R.A.	18	5/32	26	11/64	4 1/2	2 1/2	211	11/32	314	1.1	194	11/32	0.6
140	4 "	1,050	491	10	10	2 R.A.	18	5/32	33	7/32	2 1/2	4 1/2	211	11/32	314	1.1	194	11/32	0.6
141	2 "	1,900	492	20	20	1 B.S.F.	15	3/16	33	7/32	1 1/2	8 1/2	186	7/16	250	1.2	177	7/16	0.8
142	2 "	1,900	506	20	20	1 B.S.F.	15	3/16	33	7/32	1 1/2	8 1/2	186	7/16	250	1.2	177	7/16	0.8
143	1 B.S.F.	3,450	493	25	25	5/16 "	2	1/2	45	9/32	2 1/2	5 1/2	268	9/16	308	2.5	235	9/16	2.1
144	1 B.S.F.	3,450	507	35	35	5/16 "	2	1/2	45	9/32	2 1/2	5 1/2	268	9/16	308	2.5	235	9/16	2.1
145	9/13 "	4,650	494	45	45	5/16 "	2	9/32	58	5/16	2 1/2	5 1/2	280	11/16	387	3.9	280	11/16	2.9
146	9/12 "	4,650	508	60	60	5/16 "	2	9/32	58	5/16	2 1/2	5 1/2	280	11/16	387	3.9	280	11/16	2.9
147	5/16 "	5,700	495	60	60	13/32 "	25	11/32	68	23/64	2 1/2	6 1/2	307	11/16	386	5.6	306	11/16	4.4
148	11/32 "	7,150	496	70	70	7/16 "	25	11/32	73	13/32	2 1/2	6 1/2	318	15/16	396	6.6	306	11/16	4.4
149	3/4 "	8,500	497	80	80	7/16 "	31	13/32	78	29/64	2 1/2	6 1/2	338	1 1/2	405	8.1	314	15/16	6.6
150	3/4 "	10,250	498	90	90	17/32 "	34	7/16	78	1 1/2	2 1/2	6 1/2	365	1 1/2	414	9.9	337	1 1/2	8.1

0.25 in. has been allowed for "parting-off," and 6 in. waste on each 6 ft. bar.

Rule for calculating length in feet required for 1,000 pieces = $\frac{1000 \times \text{length required for 1 piece in inches}}{11}$

Weights for the barrels have been calculated for mild steel.

Material.—For Fork and Eye ends, to Spec. S.1, Pt. 1, for mild steel; for barrel, Spec. B.1 for delta metal, or to Spec. S.1, Pt. 1, for mild steel.

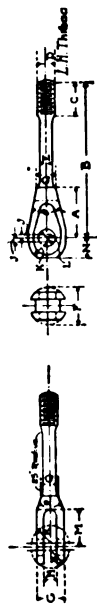
Screw threads to be in accordance with the British Association Report, No. 20, 1913, and the British Engineering Standards Association Report for Fine Threads, No. 84, 1913.

Fit.—The tape and dies used for this work should be made from the same "masters," so as to ensure "finger-tightness" of the screwing all the way down the barrel.

D.E.D.A. (Detachable Data) System
K. Borlase Matthews' Patents (provisionally protected) U.S. Patent applied for.

DIMENSIONS OF AIRCRAFT MILD STEEL TURNBUCKLES

FORK "A"



A.C.S. No.	Min. Strength.	DIMENSIONS.															TOLERANCES.										Deg.						
		A.	B.	C.	D.	E.	F.	F.	G.	H.	J.	K.	L.	M.	N.	Q.	e.	In.					In.					In.					
		- 0 + .015	- 0 + .04	- 0 + .04	In. 4 B.A. 2 1 B.S.F.	- .002 + .002	In. .32 .36 .48 .48	- .01 + .005	In. .18 .26 .33 .33	- 0 + .015	In. .08 .10 .15 .15	- 0 + .01	In. .02 .04 .06 .06	+ .001 + .005	In. .3 .3 .4 .4	- 0 + .015	In. .3 .3 .4 .4	- 0 + .01	In. .3 .3 .4 .4	- 0 + .01	In. .3 .3 .4 .4	- 0 + .01	In. .3 .3 .4 .4	- 0 + .01	In. .3 .3 .4 .4	- 0 + .01		In. .3 .3 .4 .4	- 0 + .01	In. .3 .3 .4 .4			
490	600	.35	1.1	.25	In.	.11	.32	...	.18	...	.08	.02	.37	.3	...	.3	...	.3	...	.3	...	.3	...	.3	...	.3	...	28					
491	1,030	.45	1.85	.30	2	.14	.36	...	.26	...	.10	.04	.18	.3	...	.3	...	.3	...	.3	...	.3	...	.3	...	.3	...	28					
492	1,900	.60	2.1	.40	"	.19	.48	...	.33	...	.15	.06	.24	.4	...	.4	...	.4	...	.4	...	.4	...	.4	...	.4	...	28					
506	"	.60	1.6	.40	"	.19	.48	...	.33	...	.15	.06	.24	.4	...	.4	...	.4	...	.4	...	.4	...	.4	...	.4	...	28					
493	3,450	.70	2.3	.50	1 1/4	.25	...	.62	.45	...	.20	.08	.31	.5	...	.5	...	.5	...	.5	...	.5	...	.5	...	.5	...	28					
507	"	.70	1.8	.50	"	.25	...	.62	.45	...	.20	.08	.31	.5	...	.5	...	.5	...	.5	...	.5	...	.5	...	.5	...	28					
494	4,650	.80	2.5	.60	1 1/2	.30	.72	...	.58	...	.20	.08	.36	.6	...	.6	...	.6	...	.6	...	.6	...	.6	...	.6	...	28					
508	"	.80	2.0	.60	"	.30	.72	...	.58	...	.20	.08	.36	.6	...	.6	...	.6	...	.6	...	.6	...	.6	...	.6	...	28					
495	5,700	.90	2.65	.65	1 3/4	.33	.86	...	.68	...	.25	.05	.43	.7	...	.7	...	.7	...	.7	...	.7	...	.7	...	.7	...	28					
496	7,150	.90	2.7	.70	1 3/4	.36	.90	...	.73	...	.25	.09	.45	.7	...	.7	...	.7	...	.7	...	.7	...	.7	...	.7	...	28					
497	8,500	1.0	2.85	.75	1 3/4	.40	...	1.0	.78	...	.30	.12	.50	.8	...	.8	...	.8	...	.8	...	.8	...	.8	...	.8	...	28					
498	10,250	1.15	3.1	.80	1 1/2	.44	...	1.06	.78	...	.34	.13	.53	.95	...	.95	...	.95	...	.95	...	.95	...	.95	...	.95	...	28					

DIMENSIONS OF AIRCRAFT MILD STEEL TURNBUCKLES—Continued

BARREL "B"



DIMENSIONS.														
A.	B.	C.	D.	E.	F.	G.	K.	L.	M.	e.				
TOLERANCES.														
$\begin{smallmatrix} -0 \\ +.08 \end{smallmatrix}$	$\pm .04$	$\begin{smallmatrix} -0 \\ +.04 \end{smallmatrix}$	Thread.	$\begin{smallmatrix} -0 \\ +.015 \end{smallmatrix}$	In.	In.	$\begin{smallmatrix} -0 \\ +.015 \end{smallmatrix}$	$\begin{smallmatrix} -0 \\ +.015 \end{smallmatrix}$	$\begin{smallmatrix} -.01 \\ +.005 \end{smallmatrix}$	$\begin{smallmatrix} -.02 \\ +0 \end{smallmatrix}$	In.	In.	$\begin{smallmatrix} -.02 \\ +0 \end{smallmatrix}$	Deg.
Lbs.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	
490	1.7	0	4 B.A.	.21	.3	$\frac{7}{16}$	.21	.35	...	.26	.02	.02	...	
491	3.2	0	2 " B.S.F.	.28	.4	$\frac{1}{2}$	.28	...	...	.44	...	.44	...	
492	1,900	.5	$\frac{1}{2}$ " B.S.F.	.30	.5	$\frac{3}{4}$	.38	...	...	.44	...	.44	...	
506	2.5	.5	$\frac{1}{2}$ "	.40	.5	$\frac{1}{2}$	.47	...	...	...	...	...	...	
493	3,450	.65	$\frac{1}{2}$ "	.40	.5	$\frac{1}{2}$	.47	...	...	...	...	...	...	
507	2.8	.75	$\frac{1}{2}$ "	.50	.5	$\frac{1}{2}$	.58	...	...	...	...	...	...	7
494	4,650	.75	$\frac{1}{2}$ "	.50	.5	$\frac{1}{2}$	.58	...	...	...	...	...	...	7
508	3.0	.75	$\frac{1}{2}$ "	.50	.5	$\frac{1}{2}$	.58	...	...	...	...	...	...	7
495	5,700	.75	$\frac{1}{2}$ "	.50	.5	$\frac{1}{2}$	.58	...	...	...	...	...	...	7
496	7,150	...	$\frac{1}{2}$ "	.52	.5	$\frac{1}{2}$	.60	...	...	...	...	...	...	7
497	8,500	...	$\frac{1}{2}$ "	.59	.9	$\frac{3}{4}$	.67	...	...	...	...	...	...	7
498	10,250	...	$\frac{1}{2}$ "	.62	.5	$\frac{1}{2}$	.72	...	...	...	...	...	...	7

TURNBUCKLE DIMENSIONS—Continued

EYE "C" or "E"



Oil holes must not be made more than 100' off ϕ of Turnbuckle

A.G.S. Min. No. Strength.	DIMENSIONS.															TOLERANCES.															Deg.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
	A.	B.	C.	D.	E.	F.	G.	J.	K.	L.	M.	N.	P.	e.	In.	Cwt.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.

RELATIVE MINIMUM BREAKING LOADS FOR TURN-BUCKLES OF DIFFERENT TYPES

1	2	3	4	5	6	7	8	9	10
Breaking Strength.	Range.	STANDARD CABLES (Spec. W. 2).			A.G.S.—(R.A.F.)				
		Size.	Item.	Strength of Spliced Cable. Eff. of Splice, 90 per Cent.	Mild Steel.		Min. Breaking Load.	H.T. Steel.	
					A.G.S.	Desc.		A.G.S.	Dia.
Lbs. 450 to 800	Cwt. 5	Cwt. 5	No. 0	Lbs. 504	No. 490, L	Cwt. 5	Lbs. 600	No. 138, L and 139, S	In. B.A. 6
900 to 1,350	10	10	1 & 41	1,008	491	10	1,050	140	4
1,400 to 1,500	13	..	..	..	..	..	..	..	..
1,900 to 2,000	15	15 & 20	2 & 42 3 & 43	1,512 2,016	492, L 500, S	15 to 20	1,900	141, L and 142, S	2
2,400 to 3,000	20 to 27	25	51 & 44	2,520	493, L 507, S	25 to 30	3,450	143, L 144, S	1 in.
3,250 to 4,000	30 to 35	35	52 & 45	3,528	..	..	..	..	..
4,500 to 5,000	40 to 45	45	53 & 46	4,536	494, L 508, S	45	4,650	145, L 146, S	9/32 ..
6,000 to 7,000	60 to 70	60 70	54 & 47 55	6,048 7,056	495 496	60 70	5,700 7,150	147 148	5/16 .. 11/32 ..
8,000 to 9,000	75 to 80	75 80	48 56	8,064	497	80	8,500	149	3/4 ..
10,000 to 11,000	90 to 100	90	49	9,072	498	90	10,250	..	..
15,500	140	..	..	..	..	..	..	..	..

NOTE.—Different types of turnbuckles of the same strength are not always interchangeable owing to different dimensions of Fork and Eye ends. The strength of turnbuckle used should be taken from the strength of the *splice*, and not the strength of the cable itself. In the table this is taken as 90 per cent., but it may be as low as 75 per cent.

RELATIVE MINIMUM BREAKING LOADS FOR TURN-
BUCKLES OF DIFFERENT TYPES—Continued

1	2	11	12	13	14	15	16	17	18	19	20	21	22
Breaking Strength.	Range.	ADMIRALTY.		METRIC.		AVRO.		BLACKBURN.		AMERICAN.			
		Spec. W.5.	Min. Breaking Load.	Dia.	Min. Breaking Load.	Dia.	Mark.	Min. Breaking Load.	Min. Breaking Load.	Min. Breaking Load.	Min. Breaking Load.	Min. Breaking Load.	Min. Breaking Load.
Lbs. 450 to 800	5 {	No.	Dia.	Lbs.	Mm.	Lbs.	Mm.	Lbs.	Dia.	Lbs.	No.	Lbs.	
900 to 1,350	10 {	251	4	750	4.0	775	3.5	741	..	..	1	500	
1,400 to 1,500	13 {	252	2	1,288	4.5	1,350	4.5	1,234	B.A. 4	1,050	2	1,000	
1,900 to 2,000	15 {	..	..	..	5.0	1,400	5.0	1,449	..	..	3	1,500	
2,400 to 2,500	20 {	253	B.S.F. 1/4 in.	2,408	6.0	1,950	6.0	2,128	2	1,900	4	2,000	
3,000 to 3,250	25 {	254	9/32 in	3,248	7.0	2,900	7.0	3,101	B.S.F. 1/2 in.	3,450	5	2,500	
4,000 to 4,500	30 {	255	5/16 in	3,808	8.0	4,050	8.0	3,880	..	..	6	3,000	
5,000 to 5,500	35 {	..	..	..	..	..	..	..	..	..	7	3,500	
6,000 to 7,000	40 {	..	..	..	..	..	..	..	9/32 in	4,650	8	4,000	
8,000 to 9,000	45 {	..	..	..	..	..	..	..	5/16 in	5,700	9	4,500	
10,000 to 11,000	50 {	256	3/8 in.	5,824	..	..	..	..	..	..	10	5,000	
12,000 to 13,000	55 {	..	..	..	..	..	..	..	..	..	11	6,000	
14,000 to 15,000	60 {	..	..	..	..	..	..	..	..	..	12	7,000	
16,000 to 17,000	65 {	257	7/16 in	8,064	..	..	..	..	..	..	13	8,000	
18,000 to 19,000	70 {	..	..	..	..	..	..	..	..	..	14	9,000	
20,000 to 21,000	75 {	258	1/2 in.	10,640	..	..	..	..	7/16 in	11,800	15	10,000	
22,000 to 23,000	80 {	..	..	..	..	..	..	..	1/2 in.	15,500	..	..	

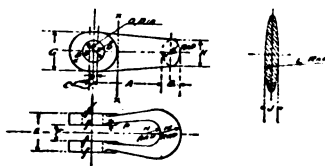
A.G.S. Turnbuckles.—With the exception of Nos. 138 and 139 these are all made in two types, viz., Fork and Eye (A.B.C.) and Double Eye (B.C.E.).

L=Long, S=Short type.

Avro Turnbuckles.—D and F are Fork and Eye types. C and E are Double Eye types.

THE AVIATION POCKET-BOOK
STANDARD AIRCRAFT SHACKLES

621.88



A.G.S. 158. Mark.	Minimum Strength.	Dimension.							
		A.	B.	C.	D.	E.	F.	G.	H.
		Tolerances.							
		-0 + .04	-0 + .02			-0 + .015	-0 + .015	-0 + .02	+0 - .02
	Lbs.	In.	In.	In.	In.	In.	In.	In.	In.
A	1,050	.55	.12	.04	.15	.22	.1	.3	.25
B	1,900	.7	.15	.04	.18	.31	.15	.36	.27
C	3,450	.8	.2	.04	.22	.42	.2	.44	.35
D	4,650	.9	.22	.04	.25	.46	.2	.5	.35
E	7,150	1.05	.3	.04	.3	.58	.25	.6	.4
F	8,500	1.2	.35	.04	.34	.66	.3	.68	.4

A.G.S. 158. Mark.	Minimum Strength.	Dimension.						
		J.	K.	L.	M.	N.	O.	P.
		Tolerances.						
		-0 + .02.					+ .001 + .002	
	Lbs.	In.	In.	In.	In.	In.	In.	In.
A	1,050	.035	.2	.8	.16	.08	5/32	...
B	1,900	.05	.22	.8	.20	.12	3/16	...
C	3,450	.07	.23	.8	.28	.15	1/2	...
D	4,650	.08	.24	.9	.32	.16	9/32	...
E	7,150	.1	.25	1.0	.37	.20	11/32	.02
F	8,500	.11	.25	1.2	.45	.24	13/32	.02

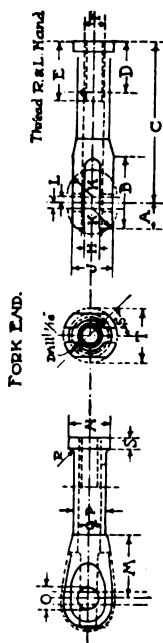
Material to Specification No. 8. 10. The shackle is only to be machined where marked *f*, but all stampings should be cleared up, so as to be free from all die marks. All shackles should be capable of being bent straight without showing signs of fracture.

All holes should not be more than 0.010 in. off the centre line of the shackle.

Part, A.G.S. 158, or Specification S.P.1.

Fork Ends, Turnbuckles, Shackles, Etc.—Continued

621.88

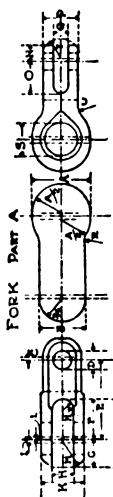
DIMENSIONS OF AIRCRAFT
FORK ENDS

A. G. S. No.		Minimum Tensile Strength.		DIMENSIONS.																				TOLERANCES.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
				A.	B.	C.	D.	E.	F.	H.	J.	K.	L.	M.	N.	O.	P.	Q.	R.	S.	T.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.

Material.—Mild steel to A.B. Specification S.1, Part 1.

Note.—Tolerances on "T" have been arranged so that steel bar of the usual sizes may be used with the minimum of machining. These fork ends are used in conjunction with both streamline wires (Specification 2W. 3) and swaged wires (Specification 2W. 8).

DIMENSIONS OF AIRCRAFT UNIVERSAL FORK JOINTS PART "A"



THE AVIATION POCKET-BOOK

621.88

A.C.S. No.	DIMENSIONS.															
	A.	B.	C.	D.	E.	F.	G.	H.	K.	L.	M.	N.	O.	P.	Q.	R.
	Min. Strength	Min. Strength	Min. Strength	Min. Strength	Min. Strength	Min. Strength	Min. Strength	Min. Strength	Min. Strength	Min. Strength	Min. Strength	Min. Strength	Min. Strength	Min. Strength	Min. Strength	Min. Strength
Lbs.	TOLERANCES.															
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
451 1,050	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015
452 1,900	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015
453 3,450	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015
454 4,650	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015
455 7,700	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015
456 8,500	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015
457 10,250	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015
458 11,800	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015
459 13,800	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015
460 15,500	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015
461 17,500	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015	-.015

Material.—Mild steel to Specification S.1, Part 1.
Note.—Tolerances on "A" dimensions have been arranged so that steel bar of the usual size may be used with the minimum of machining.
 A complete set consists of 2 forks, 2 trunnions (R. and L. hand), and 2 lock-nuts (R. and L. hand). These joints are used only in conjunction with streamline wires (see Specification 2W. 3).

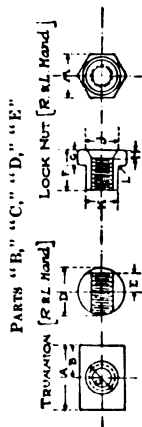
R. Bortle Matthews' Patents (provisionally protected). U.S. Patents applied for.
DE-DA (Detachable Data) System

Fork Ends, Turnbuckles, Shackles, Etc.—Continued

621.88

DIMENSIONS OF AIRCRAFT UNIVERSAL FORK JOINTS—Continued

PARTS "B," "C," "D," "E"



A.G.S. No.	Minimum Tensile Strength.	DIMENSIONS.										
		A.	B.	C.	D.	E.	F.	G.	H.	J.	K.	L.
		TOLERANCES.										
		- 0 + .02	- 0 + .01		- .004 - .010		- 0 + .01					
	Lbs.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
451	1,050	.4	.2	.11	.12	.12	.31	.15	.1	.25	.2	.02
452	1,900	.52	.26	.13	.13	.13	.45	.15	.1	.30	.24	.02
450	2,600	.6	.3	.16	.16	.16	.44	.15	.1	.34	.28	.05
453	3,450	.7	.35	.19	.19	.19	.42	.15	.1	.38	.31	.02
454	4,650	.76	.38	.20	.20	.20	.49	.15	.1	.38	.34	.02
455	5,700	.90	.45	.23	.23	.23	.50	.19	.15	.45	.37	.02
456	7,150	.94	.47	.26	.26	.26	.6	.24	.15	.5	.4	.02
457	8,500	1.04	.52	.29	.29	.29	.6	.24	.15	.5	.43	.02
458	10,250	1.10	.55	.31	.31	.31	.68	.28	.2	.6	.47	.02
459	11,800	1.12	.59	.34	.34	.34	.69	.28	.2	.65	.50	.02
460	13,800	1.24	.62	.36	.36	.36	.75	.32	.23	.75	.53	.02
461	15,500	1.3	.65	.39	.39	.39	.76	.32	.23	.75	.56	.02

Note.—These turnbuckles and lock-nuts are used in conjunction with the fork shown on previous page.
A complete Universal Fork joint consists of: Right Hand—1 Fork "A," 1 Turnbuckle "B," 1 Lock-nut "C"; Left Hand—1 Fork "A," 1 Turnbuckle "D," 1 Lock-nut "E."

AIRCRAFT UNIVERSAL FORK JOINTS (*Right and Left Hand*)

Old Type H.T. Steel.	Min. Tensile Strength.	A.G.S. No.	Fork "A." Trunnion End.		Trunnion.		Lock-Nut.		Material Req'd. to make 1,000 Forks "A" (Approx.)		
			Gap.	Outside.	Outside Dia.	Length.	Tap, R. and L.H.	Across Flats of Hex.	Length.	Dia.	Weight.
	Lbs.		In.	In.	In.	In.	In.	In.	Ft.	In.	Cwt.
333	1,050	451	.22	.36	5/16	.4	4 B.A.	.275 } .280 }	159	9/16	1.2
334	1,900	452	.26	.48	3/8	.52	2 "	.333 } .338 }	185	3/4	2.6
..	2,600	450	..	..	7/16	.6	7/32 B.S.F.	.440 } .445 }	217	13/16	3.4
335	3,450	453	.33	.66	1/2	.70	1 "	.440 } .445 }	215	1 1/8	3.9
336	4,650	454	.36	.72	17/32	.76	9/32 "	.440 } .445 }	234	1	5.6
337	5,700	455	.39	.86	19/32	.90	5/16 "	.520 } .525 }	254	1 1/16	6.9
338	7,150	456	.42	.9	21/32	.94	11/32 "	.595 } .600 }	267	1 3/16	9
339	8,500	457	.45	1.0	23/32	1.04	3/4 "	.685 } .690 }	295	1 5/16	12
340	10,250	458	.49	1.06	25/32	1.10	13/32 "	.705 } .710 }	325	1 3/8	14.7
341	11,800	459	.52	1.14	27/32	1.12	7/16 "	.705 } .710 }	345	1 1/2	18.5
342	13,800	460	.55	1.2	29/32	1.24	15/32 "	.815 } .820 }	358	1 5/8	22.5
343	15,500	461	.58	1.26	31/32	1.3	1/2 "	.915 } .920 }	378	1 3/4	27.6

Notes.—For particulars of the wiring plate end of the Universal Joint, see details given in other tables.

Material Used for forks, trunnions, and lock-nuts to be to Specification for mild steel bars, S.1, Part 1.

Screw Threads to be in accordance with the British Engineering Standards Association Report for Fine Threads, No. 84, 1918 and the British Association Report, No. 20, 1913.

Material Quantities.—0.25 in. allowed for "parting-off," and 6 in. waste on each 6 ft. bar of steel.

J.E.D.A. (Detachable Data) System

R. B. & Co. Matthews' Patents (previously protected) U.S. Patents applied for

(VII.) Tubes

621.947

AXLE TUBES

Specification.—*Material*—T.2 nickel-chrome steel seamless, cold drawn tubes are employed, which are air-hardened and tempered after drawing. *Tests* must give:—

Ultimate tensile strength, not less than 85 tons per sq. in.

Elongation on 2 in., not less than 5 per cent.

" " 4 " " " 3 "

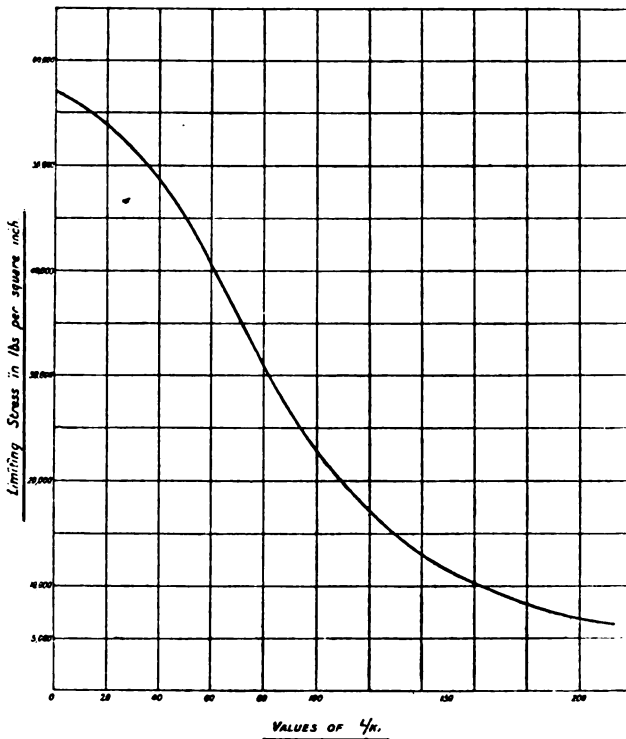
Nominal Dia.	True Outside Dia. (Lim. $\pm$.005 in.).	Thickness.		Min. Area of Section.	Max. Weight per Foot.	Modulus of Section Z.	Proof Load.	Proof Load Leverage L.
In.	In.	Gauge.	In.	In. ²	Lbs.	In. ³	Lbs.	In.
2.375	2.368	10	.128 - .000 + .010	.903	3.30	.482	2,410	35.0
2.165	2.158	10	.128 - .000 + .010	.819	3.00	.394	2,200	30.0
2.165	2.158	12	.104 - .000 + .008	.673	2.46	.331	1,930	30.0
2.165	2.158	14	.080 - .000 + .006	.524	1.92	.264	1,540	30.0
1.75	1.743	10	.128 - .000 + .010	.652	2.38	.247	1,730	25.0
1.75	1.743	12	.104 - .000 + .008	.538	1.97	.209	1,460	25.0
1.75	1.743	14	.080 - .000 + .006	.420	1.54	.168	1,170	25.0
1.75	1.743	16	.064 - .000 + .005	.339	1.24	.138	964	25.0
1.50	1.493	14	.080 - .000 + .006	.357	1.30	.120	966	21.7
1.50	1.493	16	.064 - .000 + .005	.289	1.05	.099	797	21.7
1.50	1.493	18	.048 - .000 + .004	.219	.80	.077	620	21.7
1.10	1.095	14	.080 - .000 + .006	.256	.93	.061	807	13.2

N.B.—Axle tubes are seriously weakened where drilled.

MILD STEEL TUBES

Hard Drawn and Blued.* Carbon about 0.15 per cent.
Specification T.6 (for softened tubes see Specification T.26).—If

* The term "Blued" replaces the term "Normalised" used in former specifications. Normalising has been recently defined in the B.E.S.A. Report No. 75 to describe a different heat treatment.



blued tubes are annealed, brazed, or welded, their strength will be reduced at the parts where they are so treated to 20 tons per sq. in. ultimate and 11 tons per sq. in. yield point.

Tubes under $\frac{1}{4}$ in. outside diameter are difficult to make to this specification, and should, unless strength is essential, be ordered to Specification T.26.

Tests :—

Ultimate strength in tension not less than 30 tons per sq. in.

Yield point " " " 28 " "

Yield point in compression " " " 28 " "

Bluing.—After straightening, the tubes are heated to a temperature between 380° and 450° C. in a uniformly heated muffle, and

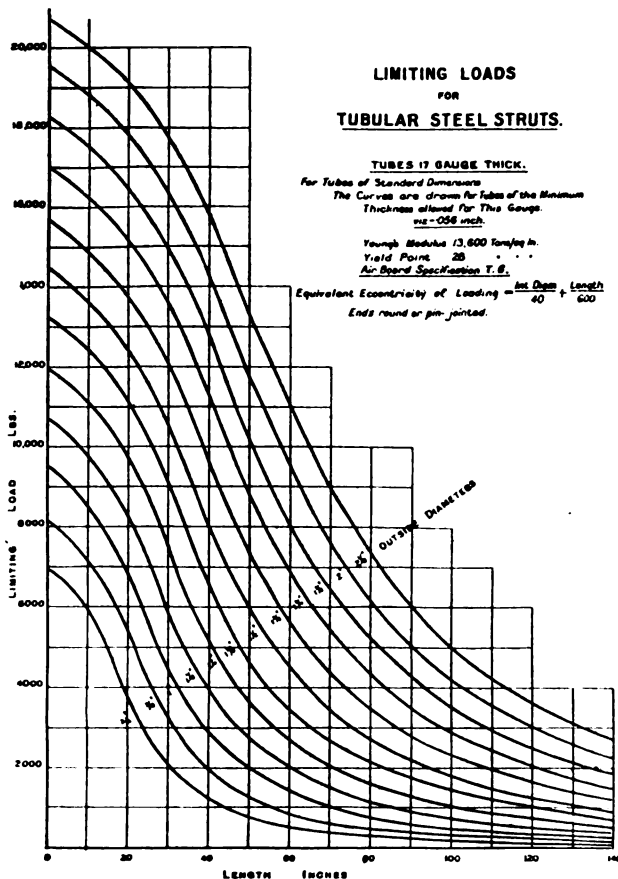
LIMITING LOADS FOR TUBULAR STEEL STRUTS.

TUBES 17 GAUGE THICK.

For Tubes of Standard Dimensions
The Curves are drawn for Tubes of the Minimum
Thickness allowed for This Gauge.
viz. 0.058 inch.

Young's Modulus 13,600 Tons/sq. in.
Yield Point 28 " " "
Air Board Specification T. 8.

Equivalent Eccentricity of Loading = $\frac{\text{Net Diam}}{40} + \frac{\text{Length}}{600}$
Ends round or pin-jointed.



after they have attained a uniform temperature throughout they are allowed to soak at that temperature for 20 minutes, and then allowed to cool freely in still air sheltered from draughts.

Half Hard* or Fully Softened. Carbon about 0.15 per cent.

* Bright drawn tubes which will stand flattening, and crushing tests are accepted as half hard.

LIMITING LOADS FOR TUBULAR STEEL STRUTS.

20 GAUGE THICK

For Tubes of Standard Dimensions (Air-Board Schedule T.10)

The Curves are drawn for Tubes of the Minimum

Thickness allowed for this Gauge.

Wt: .028 inch.

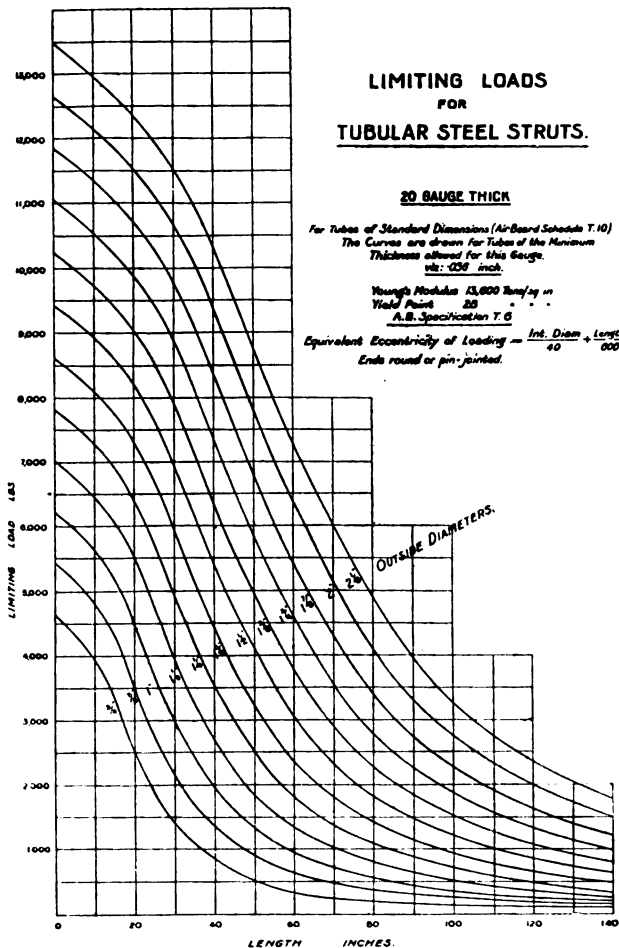
Young's Modulus 13,800 lb./sq. in.

Yield Point 20

A.S. Specification T. 6

Equivalent Eccentricity of Loading = $\frac{\text{Int. Diam.} \times \text{Length}}{40 \times 1000}$

Ends round or pin-jointed.



Specification T.26 (for blued tubes, see Specification T.6).—Tubes ordered to this specification will be delivered in a half hard condition, unless ordered to be softened outright. They must not

TABLE SHOWING WEIGHT, SECTIONAL AREA,
OF TUBES USED

(Axle Tubes)

W = Weight of Mild Steel Tube
per foot run in lbs.A = Sectional Area = $\pi(D - t)$;

Outside diameter -		$\frac{1}{4}$ "	$\frac{1}{8}$ "	$\frac{3}{8}$ "	$\frac{1}{2}$ "	$\frac{3}{4}$ "	$\frac{1}{2}$ "	$\frac{3}{4}$ "	
Decimals of an inch		.250	.3125	.375	.4375	.500	.625	.750	
17 Gauge, ".056"	{	W	.122	.162	.202	.242	.282	.362	.442
		A	.034	.045	.056	.067	.078	.100	.122
		I	.000174	.000384	.000736	.00125	.00196	.00409	.00740
		Z	.00139	.00246	.00393	.00668	.00783	.0131	.0197
20 Gauge (approx. mm.), ".036"	{	W	.0897	.116	.143	.170	.197	.250	.303
		A	.0242	.0312	.0383	.0454	.0525	.0666	.0808
		I	.000142	.000305	.000577	.000923	.00142	.00290	.00516
		Z	.00114	.00195	.00297	.00422	.00568	.00928	.0138
22 Gauge, ".025"	{	W	.0685	.0878	.107	.127	.146	.185	.223
		A	.0177	.0226	.0275	.0324	.0373	.0471	.0569
		I	.000113	.000234	.000423	.000693	.00106	.00212	.00375
		Z	.000905	.00150	.00226	.00317	.00422	.00680	.00999

Outside diameter -		$\frac{1}{8}$ "	$\frac{1}{4}$ "	$\frac{3}{8}$ "	$\frac{1}{2}$ "	$1\frac{1}{8}$ "	$1\frac{3}{8}$ "	$1\frac{5}{8}$ "	
Decimals of an inch		.625	.6875	.8125	.9375	1.0625	1.1875	1.3125	
Tubes for sockets only {	{ To take inches	$\frac{1}{2}$ "	$\frac{3}{8}$ "	$\frac{1}{4}$ "	$\frac{3}{8}$ "	1"	$1\frac{1}{8}$ "	$1\frac{1}{2}$ "	
22 Gauge (approx.) ".025"	{	W	.166	.204	.244	.282	.321	.360	.405
		A	.042	.052	.062	.071	.081	.091	.102

Telescopic Tubes.—The 17 gauge tubes (omitting the $\frac{1}{8}$ " and $\frac{1}{4}$ " sizes) form a telescopic series, each fitting over the next size $\frac{1}{8}$ in. smaller in diameter.

MOMENTS OF INERTIA, AND MODULUS OF SECTION
FOR AIRCRAFT*Excepted)*Moment of Inertia = $\frac{\pi}{64}(D^4 - d^4)$; Modulus of Section = $\frac{A}{4}\left(D - 2t + \frac{2t^2}{D}\right)$

$\frac{3}{8}$ "	1"	1 $\frac{1}{8}$ "	1 $\frac{1}{4}$ "	1 $\frac{3}{8}$ "	1 $\frac{1}{2}$ "	1 $\frac{3}{4}$ "	1 $\frac{7}{8}$ "	1 $\frac{7}{8}$ "	2"	2 $\frac{1}{4}$ "
.875	1.000	1.125	1.250	1.376	1.500	1.625	1.750	1.875	2.000	2.125
.522	.602	.683	.763	.843	.923	1.00	1.08	1.16	1.24	1.32
.144	.166	.188	.210	.232	.254	.276	.298	.320	.342	.364
.0121	.0186	.0269	.0375	.0506	.0663	.0851	.107	.132	.162	.195
.0278	.0372	.0479	.0600	.0735	.0884	.105	.122	.141	.162	.188
.357	.410	.464	.517	.570	.624	.677	.731	.784	.837	.891
.0949	.109	.123	.137	.151	.166	.180	.194	.208	.222	.236
.00836	.0127	.0183	.0253	.0340	.0444	.0567	.0712	.0880	.107	.129
.0191	.0254	.0325	.0405	.0494	.0592	.0698	.0814	.0938	.107	.121
.262	.301	.339	.378	.417	.456	.494	.533	.572	.610	.649
.0668	.0766	.0864	.0962	.106	.116	.126	.135	.145	.155	.165
.00605	.00911	.0131	.0181	.0242	.0315	.0403	.0504	.0622	.0759	.0909
.0138	.0182	.0233	.0289	.0351	.0420	.0495	.0576	.0663	.0756	.0855
1 $\frac{1}{8}$ "	1 $\frac{1}{4}$ "	1 $\frac{3}{8}$ "	1 $\frac{1}{2}$ "	1 $\frac{3}{4}$ "	1 $\frac{7}{8}$ "	...	...	...	...	...
1.4375	1.5625	1.6875	1.8125	1.9375	2.0625	...	...	...	...	...
1 $\frac{3}{8}$ "	1 $\frac{1}{2}$ "	1 $\frac{3}{4}$ "	1 $\frac{7}{8}$ "	1 $\frac{7}{8}$ "	2"	...	...	...	...	...
.437	.475	.515	.554	.592	.631	...	...	...	...	...
.111	.120	.130	.140	.150	.160	...	...	...	...	...

The 22 gauge tubes (with the socket sizes) also form a telescopic series, each fitting over the next size $\frac{1}{16}$ in. smaller in diameter.

SUPPLEMENTARY TABLE OF STANDARD SIZES OF STEEL TUBES FOR AIRCRAFT

(Specification, T.10, Supplement)

TUBES FOR STRUTS, STRAIGHTENED AND NORMALISED

Outside Diameter (Tolerance $\pm .004$ in.).	To Take	Minimum Area of Section (<i>see</i> Note).	Maximum Weight per Foot (<i>see</i> Note).	Radius of Gyration (<i>see</i> Note).
<i>Approximately 11 Gauge. Thickness, .118 in. Min. to .122 in. Max.</i>				
In.	In.	Sq. In.	Lbs.	In.
2½	2	.790	2.779	.753
2½	2½	.883	3.105	.841
2½	2½	.976	3.431	.930
3	2½	1.068	3.757	1.018
3½	3	1.161	4.083	1.106
3½	3½	1.254	4.409	1.195
3½	3½	1.347	4.735	1.283
4	3½	1.439	5.061	1.371
4½	4	1.532	5.387	1.460
4½	4½	1.625	5.713	1.548
4½	4½	1.717	6.039	1.636
5	4½	1.810	6.365	1.725

Note.—Sectional areas are calculated for tubes of minimum thickness, viz., .118, .066, .038, and .025 in. respectively.

Weights per foot are calculated for maximum thickness, viz., .122, .060, .040, and .029 in. respectively.

Radii of gyration are calculated for minimum diameter and thickness.

SUPPLEMENTARY TABLE OF STANDARD SIZES OF
STEEL TUBES FOR AIRCRAFT—Continued

(Specification T.10, Supplement)

TUBES FOR STRUTS, STRAIGHTENED AND NORMALISED

Approximately 17 Gauge. Thickness, .056 in. Min. to .060 in. Max.

Outside Diameter (Tolerance ± .004 in.).	To Take	Minimum Area of Section (see Note).	Maximum Weight per Foot (see Note).	Radius of Gyration (see Note).
In.	In.	Sq. In.	Lbs.	In.
2 $\frac{1}{4}$	2 $\frac{1}{8}$	.386	1.407	.774
2 $\frac{3}{8}$	2 $\frac{1}{4}$	.408	1.487	.818
2 $\frac{1}{2}$	2 $\frac{3}{8}$	.430	1.567	.862
2 $\frac{5}{8}$	2 $\frac{1}{2}$	.452	1.647	.907
2 $\frac{3}{4}$	2 $\frac{5}{8}$	.474	1.727	.951
2 $\frac{7}{8}$	2 $\frac{3}{4}$	.496	1.808	.995
3	2 $\frac{7}{8}$	.518	1.888	1.039
3 $\frac{1}{8}$	3	.540	1.968	1.083
3 $\frac{1}{4}$	3 $\frac{1}{8}$	.562	2.048	1.128
3 $\frac{3}{8}$	3 $\frac{1}{4}$	.584	2.128	1.172
3 $\frac{1}{2}$	3 $\frac{3}{8}$	.606	2.208	1.216
3 $\frac{5}{8}$	3 $\frac{1}{2}$	.628	2.288	1.260
3 $\frac{3}{4}$	3 $\frac{5}{8}$	.650	2.369	1.304
3 $\frac{7}{8}$	3 $\frac{3}{4}$	.672	2.449	1.348
4	3 $\frac{7}{8}$	.694	2.529	1.393
4 $\frac{1}{8}$	4	.716	2.609	1.437
4 $\frac{1}{4}$	4 $\frac{1}{8}$	.738	2.689	1.481
4 $\frac{3}{8}$	4 $\frac{1}{4}$	.760	2.769	1.525
4 $\frac{1}{2}$	4 $\frac{3}{8}$	.782	2.850	1.569
4 $\frac{5}{8}$	4 $\frac{1}{2}$	.804	2.930	1.614
4 $\frac{3}{4}$	4 $\frac{5}{8}$	.826	3.010	1.658
4 $\frac{7}{8}$	4 $\frac{3}{4}$	.848	3.090	1.702
5	4 $\frac{7}{8}$	.870	3.170	1.746

Note.—Sectional areas are calculated for tubes of minimum thickness, viz., .118, .056, .036, and .025 in. respectively.

Weights per foot are calculated for maximum thickness, viz., .122, .060, .040, and .029 in. respectively.

Radii of gyration are calculated for minimum diameter and thickness.

SUPPLEMENTARY TABLE OF STANDARD SIZES OF STEEL TUBES FOR AIRCRAFT—Continued

(Specification T.10, Supplement)

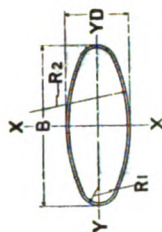
TUBES FOR STRUTS, STRAIGHTENED AND NORMALISED

Outside Diameter (Tolerance ± .004 in.).	To Take	Minimum Area of Section.	Maximum Weight per Foot.	Radius of Gyration.
<i>Approximately 20 Gauge. Thickness, about 1 mm., from .036 in. Min. to .040 in. Max.</i>				
In.	In.	Sq. In.	Lbs.	In.
2 $\frac{1}{4}$	...	.250	.946	.781
2 $\frac{1}{2}$	...	.278	1.053	.869
2 $\frac{3}{4}$	...	.307	1.160	.958
3	...	.335	1.267	1.046
3 $\frac{1}{4}$	...	.363	1.374	1.135
3 $\frac{1}{2}$	...	.392	1.481	1.223
<i>Approximately 22 Gauge. Thickness, .025 in. Min. to .029 in. Max.</i>				
2 $\frac{1}{4}$	2 $\frac{3}{16}$	.174	.689	.785
2 $\frac{1}{2}$	2 $\frac{1}{8}$	.184	.728	.829
2 $\frac{3}{4}$	2 $\frac{7}{16}$	.194	.767	.873
2 $\frac{1}{2}$	2 $\frac{1}{4}$	.204	.806	.917
2 $\frac{3}{4}$	2 $\frac{3}{8}$	.214	.844	.962
2 $\frac{1}{2}$	2 $\frac{1}{2}$	.224	.883	1.006
3	2 $\frac{1}{2}$	.233	.922	1.050
EXTRA TUBES FOR SOCKETS ONLY				
<i>Approximately 22 Gauge. Thickness, .025 in. Min. to .029 in. Max.</i>				
2 $\frac{3}{16}$	2 $\frac{1}{4}$	.169	.670	...
2 $\frac{5}{16}$	2 $\frac{1}{4}$	.179	.709	...
2 $\frac{7}{16}$	2 $\frac{3}{4}$	.189	.747	...
2 $\frac{1}{2}$	2 $\frac{1}{2}$	.199	.786	...
2 $\frac{1}{2}$	2 $\frac{3}{4}$	.209	.825	...
2 $\frac{3}{4}$	2 $\frac{3}{4}$	.219	.864	...
2 $\frac{1}{2}$	2 $\frac{3}{4}$	.228	.902	...
3 $\frac{1}{16}$	3	.238	.941	...

OVAL STEEL TUBES FOR AIRCRAFT

(Specification T.11. Material to Specification T.1 or T.6)

SCHEDULES OF STANDARD SIZES AND PROPERTIES OF SECTIONS



• Outside Diameters.		Minimum Area of Section.	Weight per Ft. Run of Tube of Maximum Section.	Radii of Gyration.		Moduli of Section.		Limiting Bending Loads at 10 in. Overhang.	
B. Tolerance $\pm \frac{1}{16}$ per Cent. of B.	D. Tolerance ± 1 per Cent. of D.			About Axis X.X.	About Axis Y.Y.	About Axis X.X.	About Axis Y.Y.	W _x .	W _y .
17 Gauge. Thickness, .056 in. to .060 in.									
In.	In.	Sq. In.	Lbs.	In.	In.	In. ³	In. ³	Lbs.	Lbs.
1	.4	.120	.436	.298	.132	.0214	.0105	132	66
1½	.5	.151	.556	.377	.170	.0344	.0176	216	110
1¾	.6	.184	.673	.455	.208	.0513	.0268	321	168
2	.7	.217	.791	.534	.246	.0711	.0379	446	238
2½	.8	.249	.910	.613	.284	.0943	.0509	592	319
2¾	.9	.282	1.028	.692	.322	.1204	.0659	756	412
3	1.0	.314	1.147	.771	.361	.1503	.0827	943	518

OVAL STEEL TUBES FOR AIRCRAFT—Continued

(Specification T.11. Material to Specification T.1 or T.6)

SCHEDULES OF STANDARD SIZES AND PROPERTIES OF SECTIONS

Outside Diameters.		Minimum Area of Section D.	Weight per Ft. Run of Tube of Maximum Section.	Radii of Gyration.		Moduli of Section.		Limiting Bending Loads at 10 in. Overhang.	
B. Tolerance $\pm \frac{1}{2}$ per Cent. of B.	D. Tolerance ± 1 per Cent. of D.			About Axis X-X.	About Axis Y-Y.	About Axis X-X.	About Axis Y-Y.	W.r.	W.y.
20 Gauge. Thickness, .038 in. to .040 in.									
In.	In.	Sq. In.	Lb.	In.	In.	In. ³	In. ³	Lbs.	Lbs.
1	.4	.079	.289	.304	.139	.0147	.0077	.92	.48
1 $\frac{1}{4}$	.5	.100	.378	.383	.177	.0236	.0127	148	80
1 $\frac{1}{2}$	.6	.121	.457	.462	.216	.0345	.0189	217	118
1 $\frac{3}{4}$	.7	.142	.536	.541	.254	.0476	.0264	299	165
2	.8	.163	.616	.619	.292	.0628	.0350	394	220
2 $\frac{1}{4}$	.9	.184	.695	.698	.330	.0800	.0449	502	282
2 $\frac{1}{2}$	1.0	.205	.774	.777	.368	.0994	.0562	623	352

OVAL STEEL TUBES FOR AIRCRAFT—Continued
(Specification T. 11. Material to Specification T. 1 or T. 6)

SCHEDULES OF STANDARD SIZES AND PROPERTIES OF SECTIONS

Outside Diameters.		Minimum Area of Section.	Weight per Ft. Run of Tube of Maximum Section.	Radii of Gyration.		Moduli of Section.		Limiting Bending Loads at 10 in. Overhang.	
B. Tolerance $\pm \frac{1}{16}$ per Cent. of B.	D. Tolerance $\pm \frac{1}{16}$ per Cent. of D.			About Axis X'X.	About Axis Y'Y.	About Axis X'X.	About Axis Y'Y.	W'.x.	W'y.
In.	In.	Sq. In.	Lbs.	In.	In.	In. ³	In. ³	Lbs.	Lbs.
$\frac{5}{8}$	.25	.0341	.134	.189	.086	.0039	.0020	24	13
$\frac{7}{8}$	.3	.0413	.163	.228	.105	.0058	.0031	36	19
1	.4	.0559	.220	.307	.143	.0106	.0058	67	36
$1\frac{1}{4}$	.5	.0704	.278	.386	.181	.0169	.0094	106	59
$1\frac{3}{4}$	.6	.0849	.335	.465	.220	.0246	.0138	154	86
$1\frac{7}{8}$	.7	.0996	.392	.544	.258	.0338	.0191	212	119
2	.8	.1140	.450	.623	.296	.0444	.0250	278	156

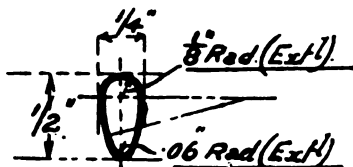
Approximately 22 Gauge. Thickness, .025 in. to .029 in.

STANDARD STEEL TUBES OF SPECIAL SECTIONS

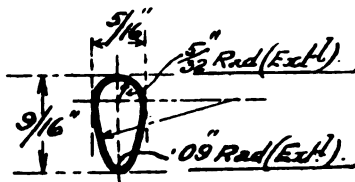
(Specification 2 T.12).

(For round tubes see Specification T.10; for oval tubes see Specification T.11; for streamline tubes see Specification T.13).— These tubes are not suitable for parts which are highly stressed.

The tubes are only made in the sizes and thicknesses shown on the accompanying drawings. If solid drawn, the tubes should be made to Specification T.26. If welded, the tubes should be of equal quality, except exhaust pipes, which may be hot finished.



$\frac{1}{2}$ -In. Aerofoil Edge and Sockets for $\frac{1}{8}$ -in. Edge.
Weight, 0.11 lb. per ft.



$\frac{5}{8}$ -In. Aerofoil Edge and Sockets for $\frac{1}{2}$ -in. Edge.
Weight, 0.13 lb. per ft.
Limits, $\pm .01$ in.

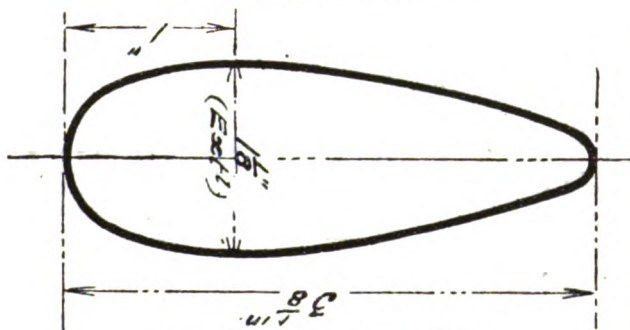


Squares. External Dimensions.

$\frac{1}{4}$ In., $\frac{3}{8}$ in., $\frac{1}{2}$ in., $\frac{5}{8}$ in. Rad., .05, 17, and 20 gauge.
 $\frac{3}{4}$ In., $\frac{7}{8}$ in., 1 in., $1\frac{1}{8}$ in., $1\frac{1}{4}$ in., $1\frac{3}{8}$ in., $\frac{1}{2}$ in. Rad., .15, 17, and 20 gauge.
 $1\frac{1}{8}$ In., $1\frac{3}{8}$ in., $1\frac{1}{2}$ in., 2 in. Rad. .15, 17 gauge, and .09 in. thick.
Limits, $\pm .01$ in.

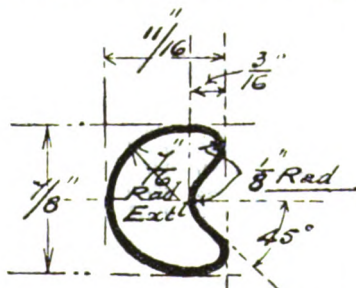
WEIGHTS

	$\frac{3}{4}$ In.	$\frac{1}{2}$ In.	1 In.
Gauge.	Lb.	Lb.	Lb.
17	0.520	0.623	0.725
20	0.358	0.426	0.494



Streamline Exhaust Pipe. (20 G.)

Not to be formed from solid drawn tube. Weight, 0.97 lb. per ft.



Cowl Ring Edge. (22 G.) Weight, 0.26 lb. per ft.

Tubes of this form are only to be used as exhaust pipes; they are to be welded, not solid drawn. Larger sizes of the same form may, if required, be obtained, but large exhaust pipes are preferably made by hand and riveted up.

STREAMLINE STEEL TUBES FOR AIRCRAFT

(Spec. T.13: for Aerofoil Edges and Exhaust Tubes, see Spec. T.12)

DIMENSIONS OF STANDARD SIZES

Standard Stream-line.	B. Maxi- mum Ex- ternal Dia- meter. Tol- erance $\pm \frac{1}{2}$ per Cent.	D. Mini- mum Ex- ternal Dia- meter. Tol- erance ± 1 per Cent.	C. Centre of Gravity below Nose.	R 1.	R 2.	R 3.	R 4.	External Dia- meter of Equi- valent Round Tube.
				External Radii.				
No.	In.	In.	In.	In.	In.	In.	In.	In.
1	3.4	1.175	1.628	7.637	2.35	0.540	0.242	2.463
2	3 $\frac{1}{2}$	1.080	1.495	7.02	2.160	0.497	0.222	2.287
3 and 5	2 $\frac{1}{2}$	0.950	1.316	6.175	1.900	0.437	0.196	1.995
4 and 6	2	0.691	0.957	4.485	1.381	0.318	0.142	1.450

PROPERTIES OF STANDARD SIZES

Standard Stream-line.	Minimum Area of Section.	Weight per Foot. Maximum Section.	Radii of Gyration.		Modulus.		Moment of Inertia.	
			About X'X'.	About Y'Y'.	About X'X'.	About Y'Y'.	About X'X'.	About Y'Y'.
Mean thickness, $\cdot 056 - \cdot 0$ + $\cdot 004$ in.								
No.	In. ²	Lbs.	In.	In.	In. ³	In. ³	In. ⁴	In. ⁴
1	.4235	1.54	1.045	0.426	.261	.131	.4624	.0769
2	.389	1.412	0.960	0.390	.2196	.1094	.3580	.0591
3	.341	1.239	0.842	0.340	.1685	.0829	.2415	.0394
4	.245	0.890	0.608	0.241	.0868	.0414	.0906	.0143

Mean thickness, .036 - 0
+ .004 in.

No.	In. ²	Lb.	In.	In.	In. ³	In. ³	In. ⁴	In. ⁴
5	.2213	0.8335	0.847	0.348	.1108	.0566	.1590	.0268
6	.1599	0.602	0.613	0.249	.0576	.0287	.0601	.0099

COPPER TUBES FOR AIRCRAFT

(Specification 2 T.7)

The copper employed in the manufacture of the tubes should contain not less than 99.25 per cent., with between 0.25 and 0.45 per cent. of arsenic.

Tensile Test :—

Ultimate stress (*annealed*), not less than 14 tons per sq. in.

Elongation, not less than 35 per cent. on a 2-in. length.

NOTES.—Tubes .028 in. thick are too thin for brazing to unions, etc., but may be soft soldered.

Tubes .036 in. thick are thick enough for brazing to unions, etc. This gauge should be used for all oil and petrol connections and for general purposes wherever possible.

Tubes of Class B. .064 in. thick should only be used where flanging or severe mechanical work has to be done on them.

SEAMLESS ANNEALED COPPER TUBES

	Hydraulic Test. Lb.-in. ²	Nominal Thickness.		Tolerance on Thickness. Inch.	Outside Diameter in Inches.									
					Tolerances ± 0.003 .					± 0.004 .				
					...	...	...	...	...	...	...	...	...	± 0.006 .
B, For oil, petrol, and general purposes.	100	Inch.	S. W. G.	Plus or Minus.	...	...	...	...	...	...	...	...	...	...
	100	0.28	22	0.002	...	...	...	...	...	...	...	...	...	...
	100	0.36	20	0.002	...	...	...	...	...	...	...	...	...	...
	100	0.48	18	0.004	...	...	...	...	...	...	...	...	...	...
	100	0.64	16	0.004	...	...	...	...	...	...	...	...	...	...
C, Compressed air, oxygen and hydrogen.	4,000	0.64	16	0.004	...	...	...	...	...	...	...	...	...	...
					...	...	...	...	...	...	...	...	...	...
D, C. C. gear and oxygen connections.	6,000	0.32	22	0.002	...	...	...	...	...	...	...	...	...	...
	6,000	0.48	18	0.003	...	...	...	...	...	...	...	...	...	...
	6,000	0.64	16	0.004	...	...	...	...	...	...	...	...	...	...

SCOUTING AND SIGNALLING

Military Information—Hague Conventions—Strategical Reconnaissance—Reports — Sketch Maps — Ranges of Artillery—Signalling — Morse International and Army Codes—Spacing and Length of Signals—Punctuation and Miscellaneous Signals — Signalling of Time — Memorising the Morse System—Semaphore Alphabet—Wireless Telegraphy.

MILITARY INFORMATION

THE following extracts from International Conventions bear on the military use of aircraft. It is to be emphasised that as the Central European Powers appear to disregard these Conventions, the articles have—with the exception of those dealing with Neutral Powers—lost much of their significance :—

Petrograd (1868).—No explosive or incendiary projectile of less weight than 14 oz. to be used.

Hague Convention (1907)—*Means of Injuring the Enemy*.—It is forbidden to kill or wound treacherously ; to kill or wound an enemy who has surrendered ; to employ arms, etc., of a nature to cause unnecessary suffering ; to destroy enemy property unless necessitated by military operations. Ruses of war, and necessary methods of obtaining information, are allowed. Attack or bombardment of undefended localities is forbidden. Notice of bombardment, except in case of assault, must, if possible, be given. In bombardments buildings devoted to religion, art, science, hospitals, etc., not used for military purposes, must be spared as far as possible ; such places to be marked with a definite sign and notified to the enemy.

Spies.—Soldiers not in disguise, or civilians carrying dispatches openly, and balloonists with dispatches or maintaining communication between parts of an army or territory, are not spies.

Rights and Duties of Neutrals.—The territory of Neutral Powers is inviolable. Belligerents are forbidden to move troops or convoys across neutral territory. Belligerent troops entering a neutral state must be interned.

The following three declarations were made :—

1. Prohibiting the discharge of projectiles and explosives from balloons or by similar means.
2. Renouncing the use of projectiles, the sole object of which is the diffusion of asphyxiating gases.
3. Renouncing the use of bullets which expand or flatten easily in the human body.

1 was not acceded to by France, Germany, Italy, Japan, Russia, and Spain; 2 and 3 were signed by practically all the Powers.

The principal duties of aircraft in warfare are:—

1. Reconnaissance, including photographing of enemy works.
2. Range finding for artillery.
3. Destruction of supplies, railways, munition stores, etc.
4. Attacking infantry, in trenches or column, and transport with machine guns.
5. Dispatching instruction at high speed.
6. Assisting the general officer commanding-in-chief to control his troops during an engagement.
7. To reach points otherwise inaccessible.
8. To carry high officials to points where their personality is needed.
9. Carrying supplies to beleaguered troops.
10. To prevent enemy aircraft carrying out similar duties.

The following, practised by British flying officers in 1911, give some idea of the requirements of a military pilot:—

Quick rising.
Passenger carrying.
Landing on unknown ground.
Flying by compass.
Testing instruments.
Observation of country.
Aerial reconnaissance.
Writing reports.
Flying in fog and clouds.
Pegging out machine at night.

Assembling and dismounting machines.
Repairs.
Preparing for transport by rail or car.
Bomb dropping and dropping messages.
Speed trials.
Engine tests.

Reconnaissance is the obtaining of information regarding (a) the topographical features and resources of a country, or (b) the movements and dispositions of an enemy. The latter may be *strategical*, *tactical*, or *protective*.

Strategical Reconnaissance comprises the location of hostile columns, their strength and direction of march before contact is established. This often involves long journeys, for which the aeroplane is particularly suited.

Tactical Reconnaissance is required to ascertain the tactical dispositions of the enemy when the armies are in touch. The collection of information by aeroplane during an engagement is not easy. Kite balloons, which remain comparatively steady while observations are made, give good results. They may be used about 3½ miles from hostile artillery for protracted work, and are often employed for observation of fire from heavy artillery. Their usefulness is, however, often considerably reduced owing to vision being obstructed by hills, ridges, etc., causing "dead" ground. Military kite balloons can be unpacked, filled, and the ascent made within half an hour, and are easily transported when packed.

It is of the greatest importance that a general should have as complete a knowledge as possible of the disposition of his troops, so that he can allocate his reserves and co-ordinate artillery fire with infantry movement. During an offensive this can be done by "contact" aeroplanes locating the position of the infantry. It may be facilitated by the latter burning glares, or carrying mirrors on their backs to reflect the light skywards. The information can then be wirelessed to Headquarters.

Scouting.—The following information should be clearly understood by the scout before starting:—

1. The special information that is required.
2. In which directions and to what distance he is required to go.
3. The method of reporting any intelligence if he is unable to return.
4. What is known of the disposition of the enemy's troops, and the disposition of his own troops and their probable movements, within his sphere of observation.

In this connection the following facts are often of use. The radius of observation at a height of 4,000 to 5,000 ft. is about 5 miles. Clouds of dust often indicate movement of troops, etc. Infantry and wagons raise a low, dense cloud, whilst the cloud raised by cavalry is high and light. In estimating the strength of columns, the time, in minutes, taken to pass a certain point, should be estimated and multiplied by the factor given below. This gives the approximate strength of the column.

Infantry in fours	-	-	-	-	200
Cavalry in sections, walking-	-	-	-	-	120
" " trotting	-	-	-	-	240
Artillery (guns or wagons) walking	-	-	-	-	5
" " trotting	-	-	-	-	10

ARTILLERY RANGES

It may be taken that the range given by maximum elevation on modern field guns is in the neighbourhood of 9,000 yds. With heavy ordnance it varies very greatly with the nature and size of the piece. Rifles are usually sighted up to about 2,200 yds., though the Lee-Enfield is graduated to 2,800 yds.

The average width over which a shrapnel shell is effective is about 25 yds., and the forward effect of the burst at effective range about 200 yds. The radius of explosion of a high explosive shell is about 25 yds.

For other than special ordnance, 9,000 ft. high is safe to be out of range. The development of special artillery is, however, proceeding rapidly.

Sir David Henderson, at the Royal Flying Corps inquiry in 1916, stated that aeroplanes had been hit at 12,000 to 14,000 ft. Shells had been observed to burst at 14,000 to 15,000 ft. One lieutenant

obtained possession of a fuse of a German anti-aircraft shell marked 7,500 metres (23,125), but at such heights as 20,000 ft., Sir David did not think the Germans would be likely to waste much ammunition on aeroplanes.

HEIGHT OF TRAVEL OF SOUND

M. Flammarion

	Altitude in Feet.
Man's shout (heard distinctly)	1,600
Sharp note of the mole-cricket	2,500
Creaking of frogs in a marsh	3,000
Man's voice and the rolling of a cart	3,255
Roll of drum and music of orchestra	4,500
Crowing of cocks	5,000
Report of a rifle and barking of a dog	5,900
Noise of a railway train in motion	8,200
Whistle of a railway engine	10,000

Reports should be divided into two parts.

1. *General description* of outstanding features of the reconnaissance enabling the reader to grasp the subject without going through unnecessary detail.

2. *Details in tabular form* if possible. Care should be taken to distinguish between what is impression or hearsay only, and what is fact. Clearness and conciseness are the first requisites. Dates and times should always be given; the hour of 12 should be specified as "noon" or "midnight," and a night referred to by the date of the day before and after, as "night 1st-2nd April." Names should be printed in block letters to avoid misunderstanding. Where foreign names are spelled in various ways, an Anglicised form should be used, followed by the local form in brackets.

A convenient method of identifying a spot on the map, if the same one is in use by the receiver of the message, is by referring him to the position of a letter in a prominent place-name, thus: "1 mile S. of the B in SALISBURY." If the map is squared and lettered the full reference should be given, say A 14 b 3.2. A indicates the large square, 14 the numbered smaller square, and b the subdivision of 14 in which the object is. 3.2 indicates that it is $\frac{3}{10}$ of the abscissa and $\frac{2}{10}$ of the ordinate from the bottom left-hand corner of the square "b." Whenever a map reference is given full details of the map from which it is taken should be quoted in the report. Reports should begin with the full designation of the officer to whom they are addressed, and end with that of the sender, and the exact time and mode of dispatch.

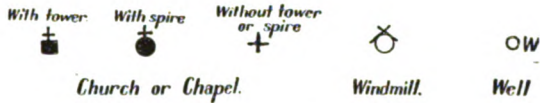
In **sketch maps** the conventional signs indicated in the diagrams herewith are used:—

Abbreviations.—P. for Post Office; T. for Post and Telegraph Office; S. P. for Sign Post.

P.E.D.4 (Detachable Data) System
© F. H. Matthews Patent (provisionally protected) U.S. Patents applied for.

Conventional Colours.—Main roads from town to town over 14 ft. wide are designated as first class. Country roads from town to village, or village to village, with under 14 ft. of metalling but in good repair, are described as second-class roads. A similar road to the latter, but in bad repair, is called third class, while unmetalled cart tracks are known as fourth class. First and second class roads are coloured yellow, when feasible.

Contours and heights should be set out in burnt sienna, but when this is not available or time does not permit, the contours are shown by chain-dotted black lines. Streams are traced out with blue (or black) lines, a double line being employed when they are over 15 ft. wide. Woods are coloured green and buildings black.

TROOPS

If colours are available British troops are coloured Red, opposing forces Blue.



Entrenchments



Cavalry in line.



Cavalry in column of route.



Cavalry in other formations.



Vedette.



Infantry in line.



Infantry in column of route.



Infantry in other formations.



Sentry.



Artillery in action.



Artillery on march.



Transport on march



Transport parked

Conventional Signs used in Field Sketching.

RULES FOR JUDGING DISTANCE

TABLE SHOWING DISTANCES AT WHICH OBJECTS CAN BE SEEN
ACCORDING TO THEIR RESPECTIVE ELEVATIONS AND THE
ELEVATION OF THE EYE OF THE OBSERVER. $D = 1.42\sqrt{H}$.

(This table applies to heights above the sea or other flat surface
when refraction is taken into account.)

Height in Feet.	Distance in Miles.	Height in Feet.	Distance in Miles.
5	3.16	200	20.04
10	4.48	300	24.54
15	5.50	400	28.34
20	6.34	500	31.62
25	7.10	600	34.78
30	7.76	700	37.57
35	8.40	800	40.16
40	8.98	900	42.60
45	9.51	1,000	44.72
50	10.02	1,500	54.99
60	10.97	2,000	63.37
70	11.83	2,500	71.00
80	12.67	3,000	77.61
90	13.44	3,500	84.01
100	14.14	4,000	89.68
150	17.35	5,000	100.40

Thus, an object 20 ft. high will be visible to the observer whose eye is elevated 300 ft. above the water or other flat surface, $(6.34 + 24.54) = 30.88$ miles.

Distances are **overestimated** :—

1. When the background and the object under observation are of the same colour.
2. When the object is in the shade, or is only partially seen.
3. In mist or failing light.

Distances are **underestimated** :—

1. When the background and the object under observation are of different colours.
2. When the sun is behind the observer, or when the light is very strong.
3. When the object is seen over water or a deep chasm.
4. When the object is very large.
5. Always when looking downwards from the air, or in looking upwards.

Constant practice is essential to become proficient at rapidly judging distances.

RULES FOR AVIATION

As in the case of navigation, it is imperative that a code of rules be observed in the steering of airships and aeroplanes, so that the dangers of collision may be avoided. The following preliminary code has been prepared by the Royal Aero Club :—

Cross-Country Flying

(a) Two aircraft meeting each other end on, and thereby running the risk of a collision, must always steer to the right. They must, in addition to this, pass at a distance of at least 100 m. taken between their nearest adjacent points.

(b) Any aircraft overtaking another aircraft is responsible for keeping clear, and must not approach within 100 m. on the right or 300 m. on the left of the overtaken craft, and must not pass directly underneath or over such overtaken aircraft.

The distance shall be taken between the nearest adjacent points of the respective aircraft. In no case must the overtaking aircraft turn in across the bows of the other aircraft after passing it so as to foul it in any way.

(c) When any aircraft are approaching one another in cross directions, then the aircraft that sees another aircraft on its right hand forward quadrant must give way, and the other aircraft must keep on its course at the same level till both are well clear.

Exception.—In the case of airships the distance of 100 m. prescribed above shall be increased to 500 m.

Flying Grounds

The following special regulations apply only to flying grounds :—

(d) Two aircraft meeting each other end on, and thereby running the risk of a collision, must always steer to the right. They must, in addition to this, pass at a distance of at least 30 m. taken between their nearest adjacent points.

(e) Any aircraft overtaking another aircraft is responsible for keeping clear, and must pass outside the overtaken craft at least a clear 30 m. distance. In no case must the overtaking aircraft turn in across the bows of the other aircraft after passing it, so as to foul it or risk a collision, and must, in addition, conform to the following regulations :—

1. If flying on the same level, i.e., within 5 m. above or below, must pass outside the overtaken aircraft at not less than 10 m.

2. If on a different level, must not pass nearer than 10 m.

The distance shall be taken between the nearest adjacent points of the respective aircraft.

An aircraft when being overtaken shall not alter its course or level, save when in the act of overtaking and passing another aircraft

Flying to the Danger of the Public

1. Flying to the danger of the public is prohibited ; particularly, unnecessary flights over towns or thickly-populated areas, or over places where crowds are temporarily assembled, or over public enclosures at aerodromes at such a height as to involve danger to the public.

2. Flying is also prohibited over river regattas, race meetings, meetings for public games and sports, except flights specially arranged for in writing with the promoters of such regattas, meetings, etc.

Note.—From 0 degrees (*i.e.*, straight ahead) to 90 degrees on the right hand constitutes the forward quadrant.

ACCIDENTS

Accidents may be classified generally as being due to the following causes, or combinations thereof :—

- (a) Engine stoppage at insufficient height.
- (b) Errors in piloting, owing to :—
 - (i.) Want of experience.
 - (ii.) Incomplete instruction.
 - (iii.) Errors of judgment.
 - (iv.) Taking undue risks.
- (c) Breaking down of aeroplane, owing to :—
 - (i.) Design.
 - (ii.) Construction.
 - (iii.) Materials.
- (d) Dangerous manoeuvres.
- (e) Unfavourable weather.
- (f) Fire.
- (g) Indisposition of pilot.

*Detachable Data System U.S. Patents applied for.
 K. R. L. M. Patents (provisionally protected)*

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NOTE

THE form or nature of each book is (in accordance with the International Classification system) indicated by the following additions to the main classification numbers:—

- ... (02) Treatise of . . .
- ... (022) Elements of . . .
- ... (021) Complete scientific treatise of . . .
- ... (023) Small treatise or rudiments of . . .
Hand-book, Pocket-book.
- ... (05) Periodicals of . . .
- ... (058) Directory of . . .
- ... (08) Polygraphs.
- ... (083) Tables of results.
- ... (084) Iconography and cartography. Drawings, photographs, diagrams of, etc.
- ... (085) Commercial catalogues of . . .
- ... (09) History of . . .

Books published prior to 1917 (with certain exceptions of special interest) are omitted. For particulars of these earlier books, see previous editions of the "Aviation Pocket-Book."

To further economise space, publishers' addresses are not given, as the name is all that a bookseller requires. These books can also be obtained from Crosby Lockwood & Son, 5 Broadway, Westminster, S.W. 1, on sending remittance to cover the price, plus 6d. for postage.

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An introduction to the aerofoil theory of screw propulsion. The subject of air-screw design is presented in as simple a manner as possible, and the results for the design of an air-screw to fulfil any specified outside conditions have been put into such a form that the design can be correctly carried out by the rules given.

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Contains much useful scientific data that has not hitherto been so accessible. A criticism is included of some of the more important carburettors.

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Detailed descriptions of the principal German engines from official sources. A very useful compilation, both from a practical and a historical point of view.

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A very practical book, exceptionally well illustrated, dealing with the design, construction, and repair of aeronautical engines. The chapters on repair and maintenance are distinctive, as the information given is usually not readily available.

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A large chart which outlines all the parts of a typical aeroplane engine installation. Indications are given as to the points where trouble is apt to occur, and suggestions are made for remedying common defects.

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- An encyclopedia and year-book of the more important facts, data, and particulars concerning the design, construction, structural materials, piloting, and navigation of flying machines. With meteorological, signalling, bibliography, and glossary sections, of value to all interested in aeronautics.

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A very concise, useful, and practical guide to the ready recognition of different types and makes of aeroplanes. Based on a logical and unique system.

KEMPE, H. R. 629.13.(023)

1919. **The Engineer's Year-Book :** with the collaboration of eminent specialists. 2,200 pp. ; over 1,700 ill. ; 18 cm ; 26th year of publication. Net 25s. (Crosby Lockwood.)

A reference book or compendium of high standing containing important formulæ, rules, tables, and data concerning the practice of general engineering. More tables and data would have necessarily to be incorporated in the "Aviation Pocket-Book," were it not for the existence of such a publication as this. It is annually revised by specialists and brought up to date, and forms the most useful work of the kind extant.

MACKROW, CLEMENT. 629.13.(023)

1919. **The Naval Architect's, Shipbuilder's, and Marine Engineer's Pocket-Book.** Lloyd Woollard, joint author. Thirteenth edition. 742 pp. ; 264 ill. ; 17 cm. 16s.

A compendium of formulæ, rules, and tables pertaining to marine engineering. There is much of interest to an aeronautical engineer, especially as regards propellers and the movement of bodies through fluids. 42 pages are devoted to aerodynamics and aeronautics.

COLVIN, FRED HERBERT. 629.13.(023)

1918. **Aircraft Mechanics' Handbook :** a collection of facts and suggestions from factory and flying field, to assist in caring for modern aircraft. 402 pp. ; ill. ; dgs. ; 18½ cm. 12s. 6d. (New York : M'Graw-Hill.)

A summary of modern practice.

WADE, W. L. 629.13.(023)

1918. **The Flying Book.** 275 pp. ; 180 ill. ; 21 cm. 5s. (Longmans Green.)

Contains silhouette drawings and brief descriptions of about 140 aeroplanes and over 100 aero engines. Also includes a directory, a "Who's Who", List of War Honours, and a Glossary of nearly 300 words, together with other general information.

PERCHERON, MAURICE. 629.13.(023)

1917. **Agenda de l'aviateur.** V. dgs. ; 15½ cm. (Paris : Nancy, Berger-Levrault.)

GREY, C. G. 629.13.(023)

1918. **Jane's All the World's Aircraft.** Ninth edition. 560 pp. ; 20 cm. x 30 cm. 21s. (Sampson Low, Marston & Co. Ltd.)

GLOSSARIES AND DICTIONARIES

DOMMETT W. E. 629.13.(023)

1917. **A Dictionary of Aircraft.** 52 pp.; 18 cm. Net. 2s.
(Electrical Press Ltd.)

A glossary of over 500 aeronautical terms.

STEPHENS, H. J. 629.13.(023)

1918. **Glossary of Aeronautical Words and Phrases.** 60 pp.;
18 cm. Second edition. Net 1s. (Aircraft, 69 Bishopsgate,
E.C.2.)

Contains definitions of over 500 terms, and a number of good
diagrams to illustrate the same. A brief English-French vocabulary is
included.

U.S. ADVISORY COMMITTEE FOR AERONAUTICS. 629.13.(023)

1918. **Nomenclature for Aeronautics.** 10 pp.; 25½ cm. (National
Advisory Committee for Aeronautics. Report No. 15.)

GREY, C. G. 629.13.(023)

1918. **Jane's Pocket Aeronautical Dictionary.** 30 pp.; 16 cm.
Net 1s. (Sampson Low, Marston.)

Includes about 300 technical and slang terms, also an abbreviated
English-French vocabulary. Reference is easily made to the drawings,
as there are lettered squares on the latter.

WATERMAN, WALDO DEANE. 629.13.(023)

1917. **Nomenclature for Aeronautics.** 31 pp.; 15 cm. (Berkeley,
Cal.: Lederer, Street & Suez.)

PAGÉ, VICTOR WILFRED. 629.13.(023)

1917. **Glossary of Aviation Terms.** Joint author, Lieut. Paul
Montariol. 94 pp.; ill.; 19½ cm. 5s. (Crosby Lockwood.)

Lists of words in both English and French, divided into four sections
—(1) Flying field terms; (2) Aeroplane terms; (3) Engine terms;
(4) Shop and tool terms.

CHINARD, GILBERT. 629.13.(023)

1917. **Handbook of English and French Terms for the Use of
Military Aviators.** Joint author, Earle Raymond Hedrick.
48 pp.; ill.; 16 cm. (Berkeley: University of California Press.)

LYCETT, JOHN. 629.13.(023)

Technical Dictionary of Aviation. English-French and
French-English. 6s. (Technical Publishing Co., also Dunod et
Pinat, Paris.)

GRAMONT, ARMAND ANTOINE AGÉNOR, duc de Guiche. 629.13.(023)

1918. **The Aviator's Pocket Dictionary and Table-Book,
French-English and English-French: a handbook for the use**

THE AVIATION POCKET-BOOK 629.13.016

of aviators and engineers in the United States Army, based on the official "vocabulaire" issued by the French War Department, with tables of measurements in American and English measures and English measures and their metrical equivalents. 120 pp.; tables; 19 cm. (New York: Brentano's.)

DYKE, A. L. 629.13.(023)

1919. **Dyke's Auto Encyclopedia.** 916 pp.; ill.; 23 cm. Eighth edition. 21s. (S. G. Gillam.)

PATENT OFFICE. 629.13.(023)

Abridgments of Aeronautical Patents. 21s. (Rayner & Co., 5 Chancery Lane, E.C., 1889-1918.)

A very handy book of reference, which also contains an index of void patents.

BERSEY, W. C. 629.13.(023)

1917. **Motor, Marine, and Aircraft Redbook** (a Directory). Joint author, A. Dorey. 7th year. 10s. (Technical Publishing Co.)

PERIODICAL PUBLICATIONS

Great Britain— 629.13.(05)(42)

The Aeronautical Journal. Monthly. 64 pp.; ill.; 25 cm. Net 2s. 6d. Pub. by the Royal Aeronautical Society.

The Transactions of the Royal Aeronautical Society.

Aeronautics. Weekly. 16 pp.; ill.; 28 cm. Net 6d. Pub. by Benn Bros., Ltd., and U.S. Rubber Building, New York.

Aeroplane. Weekly. 16 pp.; ill.; 30 cm. 6d. net. Pub. by Wm. Dawson Publishing Co., Ltd.

Aircraft. Monthly. 16 pp.; ill.; 30 cm. 3d. Pub. at 69 Bishops-gate, E.C.

Car and Aviation. Weekly. (Devoted to Aviation especially on the second and last Wednesdays of each month.) 24 pp.; ill.; 35 cm. 6d. Car Publishing Co.

Flight. Weekly. 16 pp.; ill.; 30 cm. 6d. net. Pub. at 38 Great Queen Street, Kingsway, W.C.2. The official organ of the Royal Aero Club of the United Kingdom.

Flying. Weekly. 16 pp.; ill.; 33 cm. 3d. net. Pub. at 5 Chancery Lane, E.C.

Continental—

Denmark: 629.13.(05)(489)

Auto, weekly, Mitchellsgade 19, Copenhagen.

Motor, weekly, Kongedybet 36, Copenhagen.

Continental—Continued**France :**

629.13.(05)(44)

- L'Aéro (daily). La Guerre Aérienne (weekly).
 L'Aerophile (monthly). Revue de l'Aerostation.
 Le Ballon. Revue de l'Aviation.
 Encyclopédie de l'Aviation.

Holland :

629.13.(05)(492)

- Avia (monthly), Wynbrugstraat 13, Rotterdam.

Italy :

629.13.(05)(45)

- La Navigazione Aerea, 52 Via Colonna, Rome.
 (Official organ of Aéro Club d'Italia.)
 Rivista della Lega Aerea Nazionale, 6 Via della Signora,
 Milan.
 Rivista del Touring Club Italiano, 14 Via Monte
 Napoleone, Milan.
 Annuario dell' Aeronautica, 14 Via Monte Napoleone,
 Milan.

Portugal :

629.13.(05)(469)

- Revista Aeronautica (Official Journal of the Ae. C. de
 Portugal), T. de Gloria 22a, 2, Lisbon.

Russia :

629.13.(05)(47)

- Aeronautical Journal of Petrograd.
 Aero, 6 Liteiny, Petrograd.
 Dans l'Empire des Aïrs, 7 Rota 26, Petrograd.
 Revue de Navigation Aérienne, 7 Rue Stremmiannaya,
 Petrograd.

Spain :

629.13.(05)(46)

- Boletín Oficial de la Asociación de Locomoción Aérea,
 20 Cataluna Square, Barcelona.
 España Automovil, 27 Calle de Arenal, Madrid.
 (Official Journal of the Real Ae. C. de España.)
 Revista de Locomoción Aérea, 20 Cataluna Square,
 Barcelona. (Official Journal of the Club of that
 name.)

Sweden :

629.13.(05)(485)

- Motor, Hautverkargat 43, Stockholm.
 Svensk Motor Tidning, Fenixpalatset, Stockholm.

Switzerland :

629.13.(05)(494)

- Bulletin de l'Aéro Club Suisse, Berne.

American—**Argentine :**

629.13.(05)(82)

- Boletín del Aero Club, Argentino (monthly), 561 St
 Martin, Buenos Aires.

American—Continued

U.S.A. : 629.13.(05)(73)

Aeronautics, 1790 Broadway, New York, and 170 Fleet Street, London, E.C., England.

Aircraft (monthly), 37 East 28th Street, New York.

Automobile and Automotive Industries, 231-241 West 32nd Street, New York.

Aviation and Aeronautical Engineering (semi-monthly), 10 c., 120 West 32nd Street, New York.

Flying (weekly), 280 Madison Avenue, New York.

Air Power, Air Service Institute of U.S., 280 Madison Avenue, New York.

Air Service Journal (weekly), 120 West 32nd Street, New York.

Journal of the Society of Automotive Engineers (monthly), New York.

Aerial Age (weekly), Madison Avenue and 40th Street, New York.

LIBRARY CATALOGUES

PATENT OFFICE. 629.13.(058)

1905. **Aerial Navigation and Meteorology**: a subject list of works in the Library of the Patent Office (573 in number). 60 pp.; 20 cm. Net 6d.

Of special value for reference as to books published prior to 1905.

HASTINGS, C. 629.13.(058)

1919. **Card Index of Aeronautical Books.** A set of over 500 printed cards, prepared by the Library of Congress, Card Division, Washington, D.C., U.S.A. The cards are of the standard size, $7\frac{1}{2}$ cm. $\times$ $12\frac{1}{2}$ cm. (about 3 in. $\times$ 5 in.). Single cards, 1 $\frac{1}{2}$ d. each, or 1d. each for a considerable number. New cards are issued whenever a new book is published.

Each card contains the author's name, the title of a book, the physical make up of the book, the date of publication, and the publisher's name. These cards are invaluable for library and cataloguing purposes, as not only do they save time and trouble, but they also include all books of importance on the subject.

BROCKETT, PAUL. 629.13.(058)

1909. **Bibliography of Aeronautics.** 940 pp. (Smithsonian Institution, Washington, U.S.A.)

A most detailed and complete work, including even articles from technical journals.

FINANCE

629.13.(058)

1918. **The Aeroplane Blue Book.** 96 pp.; 22 cm. 1s. 6d. (The Aeroplane and General Publishing Co.)

A directory of Aircraft Finance, which gives the general records of the principal companies associated with the industry.

LIGHTER-THAN-AIR CRAFT

WIDMER, EMIL JOSEPH.

629.13.011.(022)

1917. **Military Observation Balloons (Captive and Free).** A complete treatise on their manufacture, equipment, inspection, and handling, with special instructions for the training of a field balloon company. 151 pp.; ill.; 19½ cm. (New York: D. Van Nostrand Co.)

Based on balloon manual of the German Army in use at the beginning of the war. Contains much interesting information.

RICCARDO-BRAUZZI.

629.13.011.(021)

1917. **Cours d'Aéronautique Générale.** Part I. Etudes des questions intéressantes toutes les modes de locomotion aérienne. 344 pp.; 94 ill. Part II. Etude statique et dynamique des ballons en général. 410 pp.; 91 ill.; 25 cm. (Four more volumes in the Press.) 25s. per vol. (Paris: Dunod & Pinat.)

EDWARDS, JUNIUS DAVID.

629.13.011.(021)

1918. **Permeability of Balloon Fabrics.** 31 pp.; ill.; 25½ cm.; (U.S. Bureau of Standards. Technologic papers, No. 113.)

ROTH, CHARLES HARTERS.

629.13.011.(022)

1917. **A Short Course on the Theory and Operation of the Free Balloon.** 68 pp.; ill.; 29 cm. (Akron, O.: The Goodyear Tyre and Rubber Co.)

M'CULLOUGH, PAUL JAMES.

629.13.011.(022)

1917. **Spherical Ballooning:** some of the requirements. 3 pp.; ill.; 22½ cm. 4s. 6d. (St Louis: The Mangan Printing Co.)

ORCY, LADISLAS D', *ed.*

629.13.011.(058)

1917. **D'Orcy's Airship Manual:** an international register of airships, with a compendium of the airship's elementary mechanics. 4 p. l.; 232 pp.; ill.; 17 x 24½ cm. (New York: The Century Co.)

HEAVIER-THAN-AIR CRAFT. GENERAL TREATISES

LOENING, GROVER CLEVELAND.

629.13.52.(021)

1918. **Military Aeroplanes, Simplified, Enlarged:** an explanatory consideration of their characteristics, performances, construction,

THE AVIATION POCKET-BOOK 629.13.016

maintenance, and operation, specially arranged for the use of aviators and students. 3 p. l. ; 202 pp. ; ill. ; 26½ cm. 21s. (Dawson.)

BARBER, H. 629.13.52.(022)

1918. **The Aeroplane Speaks.** With 40 full pages of "types of aeroplanes." 7th edition. VII., 158 pp. ; 88 ill. ; 25 cm. 8s. 6d. (M'Bride, Nast & Co.)

An elementary text-book for prospective pilots and riggers that differs from all others. It conveys a knowledge of the principles and practice of flying in a very clear, though unusual fashion. It is well illustrated.

CAMM, SYDNEY. 629.13.52.(022)

1918. **Aeroplane Construction.** 146 pp. ; 126 ill. ; 22 cm. (Crosby Lockwood & Son.)

This book deals with the practical features of design.

BERRIMAN, A. E. 629.13.52.(022)

1917. **Aeronautics.** 24 pp. ; 21 cm. 3d. (National Home-Reading Union.)

A very good review or summary of the rise and progress of Aviation, serving as an excellent introduction to other literature on the subject.

SWINTON, ARTHUR J. 629.13.52.(022)

1918. **The £ s. d. of Flying ; and the Permanent Way of the Air.** 205 pp. ; ill. ; 19 cm. (Aeroplane and General Publishing Co.)

This book points out that commercial long distance flying is a national necessity. It contains much useful information and data in support of this claim, and should therefore be useful for reference.

HAYWARD, C. B. 629.13.52.(022)

Practical Aeronautics : with Introduction by ORVILLE WRIGHT. Net 9s. (Crosby Lockwood & Son.)

HAYWARD, C. B. 629.13.52.(022)

1913. **Building and Flying an Aeroplane :** with an introduction to the elements of flight. Net 5s. (Crosby Lockwood & Son.)

HAYWARD, C. B. 629.13.52.(022)

Practical Aviation. 774 pp. Net 16s. (Crosby Lockwood & Son.)

A comprehensive presentation of interesting and essential facts in aeronautical science.

LIGHTER-THAN-AIR CRAFT. GENERAL TOPICS

- C. G. GREY and others. 629.13.52.(022)
 1918. **The British Aircraft Industry.** (Hodder & Stoughton.)
 GRAHAME-WHITE, CLAUDE. 629.13.52.(022)
 1917. **Air Power, Naval, Military, Commercial.** Joint author,
 Harry Harper. 262 pp.; plates; 22½ cm. (Chapman & Hall.)
 629.13.52.(022)
 GRAMONT, ARMAND ANTOINE AGÉNOR DE, duc de Guiche.
 1918. **Aviator's Elementary Handbook:** a primer of aviation and
 aeroplane machines. Translated by Dwight M. Miner. 118 pp.;
 ill.; 19 cm. (New York: Brentano's.)
 CAVANAGH, GEORGE ANTHONY. 629.13.52.(022)
 1917. **Model Aeroplanes and their Engines:** a practical book
 for beginners. 152 pp.; ill.; 19½ cm. (New York: Moffat,
 Yard & Co.)
 STOUT, WILLIAM BUSHNELL. 629.13.52.(022)
 1917. **Acquiring Wings:** a text on the basic principles governing
 the design and operation of modern aircraft. 57 pp.; ill.;
 18½ cm. (New York: Moffat, Yard & Co.)

POETRY

- TATHAM, C. M. 629.13.52.(08)
 1917. **The Airman.** 16 pp.; 20 cm. Second impression. Net 8d.
 (Humphrey Milford.)
 Three short poems of unusual interest. The last, entitled "Death's
 Song," closes with the dramatic quotation . . . "and one of our airmen
 failed to return."
 SAMWAY. 629.13.52.(08)
Ballads of the Flying Corps. 2s. 6d. (M'Bride.)

HEAVIER-THAN-AIR CRAFT. BIOGRAPHIES
AND STORIES OF THE WAR

- AIMÉE (*pseud.*) 629.13.52.(09)
 1918. **An Airman's Wife:** a romance of the Flying Corps. 20 cm.
 5s. (Herbert Jenkins.)
 BISHOP, WILLIAM A. 629.13.52.(09)
 1918. **Winged Warfare.** 272 pp.; 19½ cm. 6s. (Hodder &
 Stoughton.)
 BÖLCKE, OSWALD, 1891-1916. 629.13.52.(09)
 1917. **An Aviator's Field Book:** being the field reports of Oswald
 Böelcke, from 1st August 1914 to 28th October 1916; translated
 from the German by Robert Reynold Hirsch. 203 pp.; 16 cm.
 (New York: National Military Publishing Co.)

BOTT, ALAN.

629.13.52.(09)

1917. **An Airman's Outings.** By "Contact" (*pseud.*). 323 pp.; 19 cm. 5s. (W. Blackwood & Sons.)

American edition (Garden City, New York: Doubleday, Page & Co.) has title, "The Flying Ace," also "Cavalry of the Clouds."

A good account of the Royal Flying Corps as it was in 1916 and 1917.

BRISCOR, WALTER E.

629.13.52.(09)

1917. **Captain Ball, V.C., D.S.O., of the R.F.C.** Ill.; 20 cm. (Herbert Jenkins, Ltd.)

CAMPBELL, GEORGE FREDERICK.

629.13.52.(09)

1918. **A Soldier of the Sky.** 232 pp.; 19½ cm. 6s. (Chicago: Davis Printing Works.)

COLLINS, FRANCIS ARNOLD.

629.13.52.(09)

1917. **The Air Man:** his conquests in peace and war. 241 pp.; 20 cm. (New York: The Century Co.)

DRAKE, VIVIAN.

629.13.52.(09)

1918. **Above the Battle:** with an introduction by General C. G. Hoare. 322 pp.; 19½ cm. 6s. (Appleton.)

FLIGHT COMMANDER (*pseud.*)

629.13.52.(09)

1918. **Cavalry of the Air.** 270 pp.; 6 ill.; 18 cm. 6s. (Ed. J. Burrow & Co., Ltd.; Simpkin, Marshall, Hamilton, Kent & Co., Ltd.)

A series of stories of the experiences of observers and pilots under war conditions, relating the circumstances under which the work is carried out above and beyond the lines.

GENET, EDMOND CHARLES CLINTON.

629.13.52.(09)

1918. **War Letters of Edmond Genet:** the first American aviator killed flying the stars and stripes, ed., with an introduction, by Grace Ellery Channing; prefatory note by John Jay Chapman. 330 pp.; 19½ cm. 6s. (New York: C. Scribner's Sons.)

GRANT, DOUGLAS.

629.13.52.(09)

1918. **The Fifth Ace.** Frontispiece; 314 pp.; 19½ cm. (New York: W. J. Watt & Co.)

HALL, BERT.

629.13.52.(09)

1918. **En l'air!** (In the air): three years on and above three fronts. 153 pp.; 19½ cm. (New York: The New Library, incl.)

629.13.52.(09)

HEWLETT, HILDA BEATRICE (HERBERT), "Mrs MAURICE HEWLETT."

1917. **Our Flying Men.** 40 pp.; 21½ cm. (Kettering: Printed by T. B. Hart.)

BIBLIOGRAPHY

629.13.016

M'CONNELL, JAMES ROGERS.

629.13.52.(09)

1918. **Flying for France**: with the American escadrille at Verdun. 176 pp. 19½ cm. (New York: Grosset & Dunlop.)

MELLOR, C.

629.13.52.(09)

1917. **The Airman**. Ill.; 20 cm. Net 3s. 6d. (John Lane.)

Experiences while obtaining a brevet in France.

MIDDLETON, EDGAR C.

629.13.52.(09)

1917. **The Way of the Air**. (An air pilot.) 184 pp.; 20 cm. 3s. 6d. (W. Heinemann.)

A brief account of the experiences through which a would-be pilot has to pass; also contains an interesting collection of incidents from the diary of a pilot on active service.

MIDDLETON, EDGAR C.

629.13.52.(09)

1917. **Glorious Exploits of the Air**. 255 pp.; 19 cm. 2s. (Simpkin, Marshall, Hamilton, Kent & Co., Ltd.)

Vivid tales of aerial fighting in the war.

MIDDLETON, EDGAR C.

629.13.52.(09)

1918. **Tails Up**. 314 pp.; 19 cm. 6s. (Simpkin, Marshall, Hamilton, Kent & Co., Ltd.)

A record of some of the dramatic incidents of aerial fighting in the war, told in a stirring manner, and giving an insight into the requirements of the modern fighting aeroplane.

MOLTER, BENNETT A.

629.13.52.(09)

1918. **Knights of the Air**. By a pilote-aviateur, escadrille n-102, armée française. 243 pp.; 19½ cm. 6s. (D. Appleton.)

MORTANE, JACQUES.

629.13.52.(09)

1918. **Guyener, the Ace of Aces**. Translated by Clifton Harby Levy, together with transcripts from Guyener's own note-book of flight, and photographic facsimiles of its pages. 267 pp.; 19 cm. (New York: Moffat, Yard & Co.)

NADAUD, MARCEL.

629.13.52.(09)

1918. **The Flying Poilu**: a story of aerial warfare. Translated by Frances Wilson Huard. 217 pp.; 19½ cm. 6s. (Hodder & Stoughton.)

O'BRIEN, P.

629.13.52.(09)

1918. **Outwitting the Hun**. 6s. (Wm. Heinemann.)

PORTER, MRS HORACE.

629.13.52.(09)

1917. **A Subaltern's Share in the War**. 178 pp.; ill.; 18 cm. 3s. 6d. (Constable & Co.)

The home letters of the late George Weston Devenish; the latter portion deals with his experiences as a pilot

THE AVIATION POCKET-BOOK 629.13.016

RICHTHOFEN, MANFRED ALBRECHT, *freiherr* VON. 629.13.52.(09)

1918. **The Red Battle Flyer.** Translated by T. Ellis Barker, with a preface and notes by C. G. Grey. 140 pp.; 19 cm. (Aeroplane & Gen. Pub. Co.)

The stories in this book afford an excellent insight into German aviation practice.

ROLT-WHEELER, FRANCIS WILLIAM. 629.13.52.(09)

1917. **The Wonder of War in the Air.** 347 pp.; ill.; 20½ cm. (Boston: Lothrop, Lee & Shepard Co.)

WALCOTT, STUART. 629.13.52.(09)

1918. **Above the French Lines:** letters of Stuart Walcott, American aviator. 93 pp.; 20 cm. 4s. 6d. (Princeton University Press.)

WINGS (*pseud.*) 629.13.52.(09)

1918. **Over the German Lines.** (Hodder & Stoughton.)

WING-ADJUTANT. 629.13.52.(09)

1918. **The Royal Flying Corps in the War.** (Cassell & Co.)

WING-ADJUTANT. 629.13.52.(09)

1918. **Plane Tales from the Skies.** (Cassell & Co.)

WING-ADJUTANT. 629.13.52.(09)

1918. **Over, Over There.** (Cassell & Co.)

WOOD, ERIC. 629.13.52.(09)

1917. **Thrilling Deeds of British Airmen.** 316 pp.; ill.; 19½ cm. 3s. 6d. (Geo. G. Harrap & Co.)

An excellent compilation of exciting stories, which at the same time illustrate various types and phases of aerial operations.

WINSLOW, CARROLL DANA. 629.13.52.(09)

1917. **With the French Flying Corps.** 226 pp.; plates; 19 cm. 3s. 6d. (Constable.)

The experiences of an American aviator. Of special interest, as little information is available of aerial operations outside the R.A.F.

HEAVIER-THAN-AIR CRAFT. AEROPLANE DESIGN

BARNWELL, F. S. 629.13.52.01.(021)

1917. **Aeroplane Design, and a Simple Explanation of Inherent Stability.** By W. H. Sayers. Second edition. 102 pp.; ill.; 18½ cm. 2s. 6d. (M'Bride, Nast.)

JUDGE, ARTHUR WILLIAM. 629.13.52.01.(021)

1917. **The Design of Aeroplanes.** Second edition. 242 pp.; ill.; 22 cm. 12s. (Whittaker.)

- ROE, A. V., & Co. 629.13.52.01.(022)
 1918. **Erecting and Aligning 80 H.P. Avro Biplanes, Type 504.**
 Third edition. 44 pp.; 22 cm. Net 2s. (Pub. at Manchester.)

Although this handbook has been specially prepared for Avro biplanes, the method described is suitable for erecting and aligning any tractor biplane of a similar type. Very little has been published on this subject, hence this book will be of special value to many.

- PAGÉ, V. W. 629.13.52.01.(022)
The A-B-C of Aviation. 274 pp.; 138 ill.; 20 cm. 12s. 6d.
 (Crosby Lockwood & Son.)

An elementary text-book dealing clearly with the principles of both aeroplane flight and design. The illustrations are exceptionally lucid.

- BLAKENEY, STEPNEY. 629.13.52.01.(022)
 1918. **How an Aeroplane is Built.** Second edition. 233 pp.; ill.;
 19 cm. 5s. (Aeroplane & General Publishing Co. Ltd.)

A really practical guide to the actual workshop processes employed in constructional work.

- KING, JAMES THOMAS. 629.13.52.01.(022)
 1918. **Aeroplane Construction and Assembly.** Joint author, N. W.
 Leslie. 115 pp.; ill.; 23½ cm. (Minneapolis, Minn.: Dunwoody.)

- RATHBUN, JOHN B. 629.13.52.01.(022)
 1918. **Aeroplane Construction and Operation:** including notes on
 aeroplane design and aerodynamic calculation, materials, etc. A
 comprehensive illustrated manual of instruction for aeroplane con-
 structors, aviators, aero-mechanics, flight officers, and students.
 426 pp.; ill.; 20 cm. (Chicago: Stanton & Van Vliet.)

- WOODHOUSE, HENRY. 629.13.55.01.(022)
 1918. **Text-Book of Naval Aeronautics.** 288 pp.; ill.; 30½ cm.
 (T. Werner Laurie.)

An excellent collection of unique photographs with suitable accompanying descriptive matter. Some advanced notes are included on aeronautics in relation to naval architecture.

NAVIGATION OF THE AIR

- M'MINNIES, WILLIAM GORDON. 629.13.52.(02)
 1918. **Practical Flying:** complete course of flying instruction; with
 a chapter on the medical aspects of aviation, by H. Graeme
 Anderson. 237 pp.; 100 ill.; 19 cm. 5s. (Temple Press.)

A really practical manual dealing with actual methods of tuition. Summarised instructions are a good feature.

THE AVIATION POCKET-BOOK 629.13.016

GRAHAM-WHITE (C.)

629.13.52.(02)

1918. **Learning to Fly**: reprint. Joint author, H. Harper. 112 pp.; 18 cm. 2s. 6d. and 1s. (T. Werner Laurie.)

A practical manual for beginners.

FALES, ELISHA NOEL.

629.13.52.(02)

1917. **Learning to Fly in the U.S. Army**: a manual of aviation practice. 180 pp.; ill.; 18½ cm. 6s. (New York: M'Graw-Hill.)

COLLINS, ARCHIE FREDERICK.

629.13.52.(02)

1917. **How to Fly**. 182 pp.; ill.; 19½ cm. (D. Appleton.)

RE VLEY, D. GORDON E.

629.13.52.(02)

1917. **How to Fly (the Flyer's Manual)**: a practical course of training in aviation. Arranged by Glad Lewis. 100 pp.; 14½ cm. 4s. 6d. (San Francisco: P. Elder & Co.)

BENSON, CHARLES BEVERLEY.

629.13.(02)

1918. **Map Reading for Aviators**: with a chapter on aerial navigation. 55 pp.; ill.; 17½ cm. (Ithaca, New York.)

GIDEON, SAMUEL EDWARD.

629.13.(02)

1918. **Map Reading**. Cover-title; 39 pp.; ill.; dgs.; 27 cm. (Austin, Texas: E. L. Steck.)

RUST, ARMISTEAD.

629.13.(02)

1918. **Practical Tables for Navigators and Aviators**: containing new and rapid methods for finding the longitude, azimuth and latitude, and for great circle sailing, the identification of stars, and for plotting line of position by the Sumner and Marcq Saint-Hilaire methods. 116 pp.; dgs.; 24 cm. (Philadelphia: The author.)

DIXIE, ALBERT EDWARD.

629.13.(02)

1917. **Air Navigation for Flight Officers**. 223 pp.; ill.; 22 cm. 10s. 6d. (Hogg.)

D.F.D.A. (Detachable Data) System
R. R. Lane Matthews' Patents (provisionally protected). U.S. Patents applied for.

AIR INVENTIONS COMMITTEE

This Committee is the authority appointed by the Air Ministry to investigate inventions submitted to it. Communications should be forwarded to the Air Inventions Committee, London, W.C. 2.

POINTS ON PATENTS

An application for a British patent may be made either with a Provisional or a Complete Specification. If a Provisional Specification is taken out, it is essential to file the Complete Specification within six months. It is the better plan, and cheaper in the end, to first lodge a Provisional Specification.

In accordance with the International Convention, application for patents in other countries must be made within twelve months of the first application, whether it be a Provisional or a Complete Specification. Until the twelve months has expired the patentee, therefore, has his rights fully reserved in all other countries, though he may actually have only applied for a patent in one, and so has a good opportunity for making his arrangements for placing his invention. At the same time, of course, the applicant has no power to take proceedings in any country for infringement until the patents are sealed there.

It is now the practice in Great Britain for the Patent Office examiners to make a search among specifications deposited within fifty years next before the date of application, to ascertain whether or not a new Complete Specification has been anticipated. This service renders every patent of more value than it was in earlier days, when this procedure was not adopted.

There is no great difficulty in taking out a British Patent, if the necessary instructions are carefully complied with. The application forms and regulations are readily obtainable from the Patent Office, Southampton Buildings, Chancery Lane, E.C., on payment of the stamp duties, either by post or upon personal application. If the would-be applicant has no experience in the drafting of patents, he would be well advised to consult a patent agent (it is almost essential for foreign patents), for, as in everything else, experience counts, and if the patent is to be of any value, it must have no weak points in the wording and construction.

The Patent Office publishes abstracts of patents, classified under various subjects. These are very useful for reference, to ascertain whether an invention has been forestalled. Bound copies of the Abridgments of Aeronautical Patents, with notes, are issued by Rayner & Co., Chancery Lane, E.C. The complete specifications of all patents can be consulted in the Patent Office Library; or individual copies of any patent can be purchased for 6d. each.

AIRSCREW CONSTRUCTION

THE revolutions of the airscrew are no longer limited by the possibilities of engine speed, for many engines now run at over 2,000 r.p.m., and speed reduction gearing has to be employed to make the speed conform to the normal maximum efficient airscrew speed, which appears to be about 1,200 r.p.m., and varies according to the design from 900 to 2,000 r.p.m. The diameter of the screw is always made as large as the necessary ground clearance permits. Present standards vary from 8 ft. to 11 ft. 6 in.

The majority of airscrews are two-bladed. The three- and four-bladed types are only adopted in conjunction with a comparatively large pitch, and when the speed of rotation is low, the engine shaft being then geared down. In certain cases the consideration of aspect ratio demands four-bladed airscrews.

Construction.—Modern airscrews are built up of four to eight separate stepped laminations of walnut or mahogany, as indicated in the illustration herewith. These laminations are glued together, and when set, the sections at various points are worked out in accordance with the drawings, and the rest of the material is then shaped in smooth curves to correspond. Such construction requires considerable ingenuity and skill. The adoption of other than the specified thickness of laminations, given on the drawings, necessitates the re-plotting of the lamination contours.

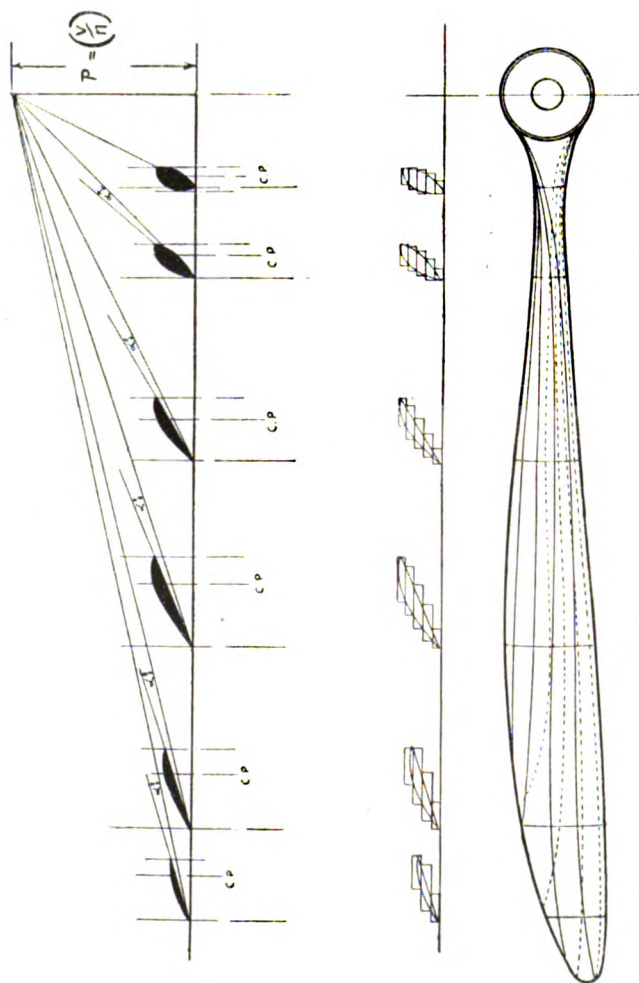
The following timbers are used:—Walnut (including black American and European varieties); the following varieties of mahogany: Nicaraguan, Honduras, and Cuban; Queensland silk wood (*Flindersia Chaturruiana*). The following may be used in part for certain airscrews:—Grand Bassam, Lagos and Benin mahogany, African iroko, English ash, Japanese walnut, silver spruce, and Benin walnut.

As a general rule timbers for use in airscrew construction should not weigh more than 40 lbs. per cubic foot, and the elastic limit on bending tests should not be less than 5,000 lbs. per square inch.

Laminated planks should be straight grained, and free from burrs, caney-grain, curls, knots, ramie figure, or worm-holes, as these are very deleterious. Further, they should not show signs of prolonged weathering, or rot in the form of dead streak, mildew, pock, or otherwise. The laminations should be cut with the

AIRSCREW CONSTRUCTION

629.13.048



grain of the timber running lengthwise and parallel to the surfaces which are to be glued together. Before use all thickened boards or cut laminations should be stored at least three weeks in a place where the temperature and atmospheric conditions are similar to those prevailing in the glue room.

Weights.—A two-bladed 7 ft. 6 in. propeller for a 60 H.P. engine weighs about 16 to 18 lbs., and a three-bladed propeller, 24 to 27 lbs.

A close approximation for estimating the weight of a propeller (W) is—

$$W = 2.5 \sqrt{\text{horse-power.}}$$

American practice gives a little greater weight, *e.g.*, the Curtiss 90 H.P. propeller weighs 32 lbs., and the 120 H.P. airscrew is 50 lbs.

Testing.—An airscrew must be most carefully balanced, for at the speed at which it runs, a slight out of balance has an appreciable effect on the operation of the machine. This test is usually carried out by placing the airscrew temporarily on a ball-bearing spindle, the ends of the latter being allowed to rest and roll if required on metal bearer rails. The sensitiveness of the apparatus employed for checking the balance of airscrews should be such that a weight of one ounce placed in a bolt-hole of an airscrew balanced thereon, should cause it to turn.

When mounted on the engine shaft the propeller should be tested for straightness. This is done by comparison of the tips successively with some fixed point. The difference should not exceed one-eighth of an inch. The blades must be of equal length, within one-sixteenth of an inch.

Airscrew vibration or flutter is usually due to faulty design or manufacture. When it occurs the airscrew should be carefully tested and checked. It must be borne in mind, however, that vibration may possibly be due to faulty operation of the engine.

Fitting an Airscrew.—Before fitting a new airscrew it should be carefully tested as suggested in the previous paragraphs. Also care must be taken to ascertain that the centre flange holes are bored true, and that they are a good driving fit for the bolts. The usual engineering precaution must be taken of tightening up all the nuts in turn, so as to distribute the strain evenly.

When the nave has been removed, in replacing it, it is of the utmost importance to see that the holding-on nut is well screwed up and locked. Following a short run after replacement, say, of three hours, it should be again tightened up and locked.

In cases where an airscrew is not fitted direct on to the nave, a flywheel should be used.

Care of an Airscrew.—When an aeroplane is brought into its hangar after its day's work, the airscrew should be wiped over, and then preferably protected by a canvas cover. Any weak spots in

the protecting varnish should be revarnished when the airscrew is dry, as it is important to prevent the wood from deteriorating.

Spare airscrews must be carefully stored in a place which is neither too dry nor too damp. They should be kept on horizontal pegs, not being allowed to lean against a wall or lie on the floor.

AIRSCREW FINISHING

(Thomas Parsons & Sons)

Varnishing Woodwork.—(a) *Woodfiller.* Apply one coat of transparent woodfiller with a stiff brush. Allow it to set for 20 minutes, and then rub across the grain with a soft cloth rag. Let the work stand overnight (or at least 12 hours) before varnishing. (b) *Undercoating Varnish.* When the woodfiller is perfectly dry, apply a full coat of undercoating copal varnish, which will dry hard within 4 to 6 hours, when it will be ready to receive the (c) *Finishing Varnish.* A full coat of finishing airscrew varnish should be applied, and the airscrew set aside till dry, which will take about 6 to 8 hours.

Enamelling Fabric Tips.—(a) *Undercoat Enamel.* Apply two coats of light grey undercoating enamel for fabric tips, allowing 4 hours between each coat. When thoroughly dry apply the (b) *Finishing Enamel.* This should consist of a full coat of dark grey finishing enamel for fabric tips, which will dry hard in 4 to 6 hours. This can then be covered with the finishing varnish at the same time as the rest of the airscrew.

Painting Boss Holes.—(a) *Filling Varnish.* Apply a medium coat of light grey filling varnish, and allow to dry for 4 hours, then finish with (b) *Waterproof Paint.* Apply a full coat of dark grey waterproof paint for boss holes, and set it aside to dry (about 4 to 6 hours).

Note.—The Authorities now insist that all materials used in the finishing of an airscrew should be supplied by one firm only, i.e., from woodfiller to finishing varnish.

AMERICAN STANDARD AIRSCREW SHAFT

On 11th January 1917 the American Society of Automotive Engineers (S.A.E.) decided upon dimensions for a standard shaft end for airscrews. This shaft end is tapered 1·2 in. per foot. The maximum diameter of the tapered portion is 2·362 in., and the length of the taper 7 in. The airscrew boss is fixed in position by a key and a 1·575 in. (40 mm.) diameter nut, with 2·5 mm. thread.

JIGS AND FIXTURES

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Hitherto British makers of aeroplanes have been builders rather than manufacturers. Possibly owing to the difficulty of securing

contracts suitable to the adaptation of repetition production, but more probably owing to the fact that makers have not realised the necessity of such organisation, the manufacture of aeroplanes is still in its infancy. Of late, however, the situation rapidly improved, for orders were placed for very large numbers of identical machines prior to the termination of the war.

In metal-working industries the use of jigs has of course been considerably developed; it is the wood-working industry that is behindhand in this respect. Economical aeroplane manufacture can only be achieved by the construction and adaptation of jigs and fixtures, each as nearly foolproof and eliminating as much hand tool work as possible. The result will not only prove a saving in labour, time, and space, but a marked improvement in the product generally. Also the output of the great majority of British works could easily be doubled, without increasing the number of employees.

Carried to the full extent, the jig and fixture system may be considered very costly at the outset, but if standard fitments are planned for the jigs, and the system of manufacture carefully thought out, it is surprising how much interchangeability can be effected. A modern aeroplane requires something like 1,200 jigs, which may cost as much as two finished machines. If, however, by their construction a saving of only 10 per cent. in labour is shown, it means that after twenty machines a greater ratio of profit is being made, and with every extra machine an extra and increasing ratio of profit will result. In practice, however, the saving in labour will be proved nearer 50 per cent., and probably even more.

Aeroplane Woodworking Jigs and Fixtures may be classified as follows:—

(1) **Parts Jigs**:—(a) *Mill jigs*—for sawing, spindling, etc., parts to their exact size.

(b) *Drilling jigs*—for drilling all the holes called for on the fittings, the necessary bolt holes, and the entering holes for large wood screws.

(c) *Parts jigs*—for completing the small built up parts, ready for attachment to components.

(2) **Component Jigs**:—(a) *Building jigs*—for assembling the various parts into a component (such as ribs, control pulley boxes, ammunition carriers, etc., etc.).

(b) *Taping and Varnishing jigs*—for assisting in the quick winding of tape where necessary, and for presenting the component in the best possible way for doping and varnishing.

These jigs usually take the form of two centre points on which the work rotates.

(3) **Unit Jigs and Fixtures**:—(a) *Unit assembly jigs*—for assembling parts and components into a unit, such as main planes, fuselage, ailerons, tail planes, etc. These should locate the exact

position for each part, and the parts, if made correctly, need not be touched by hand, the only work necessary being the insertion of necessary bolts, screws, etc., and wiring.

(b) *Unit fixtures*—take the form of benches specially made for a certain process, such as covering with fabric, doping, etc., designed to facilitate rapid handling of the unit in construction.

(4) **Erection Fixtures** are constructed to facilitate assembly of the units to the complete machine. A cradle should take the fuselage in its correct position, giving access for affixing the under-carriage, the tail skid, and the planes. A supplementary fixture gives the exact position of the wings at the tips and fuselage, and obviates the difficulty of correctly pitching the dihedral, using plumb lines, etc. A tension gauge or tautness meter should be used to determine the tautness of wiring, and by careful application a much better rigging will be ensured than is secured by the old method of straining until correct alignment is secured.

DISPOSITION OF FACTORY ACCOMMODATION

When planning or adapting a works for the manufacture of aircraft, it is extremely important that the necessary departments run in sequence to the plotted operation, with an inspection space between each process. The latest factory administration provides for an entry to stores and reissue after each operation. If an independent inspection service is in the factory, it can well be accommodated in the stores, thus being kept distinct from the works proper. Too much emphasis cannot be laid on the importance of ample store accommodation, and the vital necessity of complete and effective maintenance of a maximum and minimum number of parts in stock.

Lighting must be efficient, and lifting apparatus is necessary in the aeroplane assembly shop. Forced draught is required for the doping, brazing, metal-polishing shop ventilation, and also for the removal of wood chips in the woodworking power shops. Provision for kiln drying should be made.

In the engine machine shop, a main tank and distribution system for lubricating and cutting compounds will be found economical; on return, the compound should be filtered before recirculation.

An effective plan, giving the greatest economy in administrative expense, should show the stores in the centre of the works, with a covered approach from the main road and railway. The shops should be placed around the stores and finished units should lead to the aeroplane assembly shops, whence free access should be available either to an aerodrome or to a delivery station.

On the next page will be found tabulated the percentage distribution of the space required for aeroplane manufacturing.

SPACE REQUIRED FOR AEROPLANE MANUFACTURE. *Percentage Distribution of Covered Area*

Departments.	Complete Machines.		Complete Machines, less Engines.		Complete Machines, less Engines and Fittings.		Engines Only.		Metal Parts Only.		Woodwork and Fabric Covering without Erecting Machines.	
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
ENGINE—												
Machine shops	-	12.5	...	...	...	...	40	...	...	...	...	...
Grinding	-	1	...	...	...	...	2	...	...	...	...	...
Erection	-	7.5	...	...	...	...	20	...	...	...	...	...
Testing	-	4	...	...	...	...	10	...	...	...	...	...
METAL PARTS—												
Machine shop	-	7.5	10	...	...	...	...	...	50	...	...	...
Polishing and plating	-	1	1	...	...	...	...	...	5	...	...	...
Welding, brazing, soldering, and sand-blasting	-	1.5	2.5	...	...	...	...	...	7.5	...	...	...
Japanning	-	1	1	...	...	...	...	...	5	...	...	...
Assembly shop	-	1.5	2.5	...	...	...	...	...	3.5	...	...	...
WOODWORKING—												
Saw mill	-	3	4	7	...	...	...	...	...	...	10	...
Machine shop	-	7.5	10	12.5	...	...	...	...	...	...	20	...
Parts assembly shop	-	3	4	5	...	...	...	...	...	...	10	...
Units	-	5	6	7.5	...	...	...	...	...	...	20	...
FABRIC COVERING ROOM—												
Dope Room	-	2.5	4	5	...	...	...	...	...	...	10	...
AEROPLANE ASSEMBLY SHOPS—												
TOOLMAKING & SETTING ROOMS	-	20	26	30	...	...	...	...	...	...	...	...
STORES	-	10	12	15	...	...	...	...	5	...	2	...
DINING ROOMS AND KITCHENS	-	2	3	2.5	...	...	...	...	10	...	10	...
LOCKERS AND LAVATORIES	-	2	3	2.5	...	...	...	...	4	...	2	...
OFFICES	-	3	4	4	...	...	...	...	4	...	2	...
		100	100	100	100	100	100	100	100	100	100	100

The above scheme does not, of course, include provision for making minor standard fittings, A.G.S. parts, etc., which are usually purchased outside.

R. Borslau Matthewi Patents (provisionally protected). U.S. Patents applied for.
DE-D.A (Detachable Data) System

NON-METALLIC MATERIALS FOR AIRCRAFT CONSTRUCTION

(*Except Timber*)

Aeroplane Fabrics or Coverings

Materials.—Up to the present the general practice has been to cover the planes with a woven air-tight fabric, though suggestions have been made that vulcanised fibre, ebonite, celluloid, or aluminium sheets might be used with advantage. The material for the fabric is now chiefly unbleached linen, but cotton, calico, and silk are sometimes used. Oiled Japanese silk, muslin, oil paper, and Chinese parchment have been used by Roe, Bleriot, and others, but these materials have not proved as satisfactory as doped or painted and varnished linen fabric. In German practice, a mercerised cotton is often used on the under surface of a plane, and quite a rough material on the top side. This is a very economical practice. Cotton fabric is also still used by the Allies, though to a very small extent, and only for certain machines of lesser importance. The great difficulty with this material is the large quantity of fluffy hairs on its surface. These prevent the proper penetration of the dope, and cause minute bubbles to form in the latter, which causes the film to break up when exposed even for a short period to ordinary flying conditions, resulting in soggy planes.

Cotton fabric should weigh about 3·14 oz. per square yard, and the strength in the warp should be 66 lbs. per inch, and 63 lbs. per inch in the weft. A greater quantity of dope is required per square foot of surface for cotton than for linen.

To remove the fluffy hairs from cotton, a singeing or gassing process is adopted, but any carelessness in application is apt to singe and weaken the fabric. An alternative process is chemical scouring or "discharging," a somewhat complicated manufacturing process.

Warp, Woof, or Weft.—In describing aeroplane cloths, the ordinary technical terms used by weavers are employed. The **Warp** is the yarn running lengthwise in the cloth, while the **Woof** or **Weft** is the yarn running across the cloth, which is woven into the warp by the shuttle (*i.e.* selvage to selvage strands).

Description of Material.—The best linen fabric is made from fine flax, closely woven and unbleached. The yarns must be of uniform strength, and regular in count both in warp and woof.

The official specifications define the minimum count of yarns to be 92-96 ends per inch and 100 picks per inch; also a minimum strength of 91 lbs. per inch in the warp and 102 lbs. per inch in the woof or weft.

It is very important that the finished material should be free of size, fillers, soap, etc., as these things have a deleterious effect on

the dope. Boiled yarns, wet spun with a moderate amount of twist, should be employed. The finished fabric must be free from knots, slubs, snarls, and other defects. All non-cellulose matter must be removed, and the cloth is not to be calendered. The standard width is 36 in., and the weight, 4 oz. per square yard.

Samples of all rolls of fabric should be carefully tested. The specimen must be soaked in water for two hours before the test, and the excess water removed before testing.

The method for testing for strength is important, and a rate of loading of 150 lbs. per inch width per minute is usually specified. The specimen is to be 2 in. wide, with 7 in. between the jaws of the testing machine.

If careful attention is not given to the manner of testing, results on similar samples may differ by as much as 15 per cent., hence it is important to see that the samples are cut quite parallel to the direction of warp or weft, and that the test strip is placed in the machine so that the stress in testing runs parallel with the direction of the lengthways yarns. Also the rate of loading must be uniform.

Inaccuracy in the cutting or in the placing of the samples in the machine is indicated by the samples in the low tests not breaking evenly across. The highest results are taken as correct where the fracture occurs simultaneously across the test piece.

Weight of Fabric.—The British Government specify the undoped linen to weigh not more than 4 oz. per square yard, and the United States Army give the limits of weight as 3.75 to 4.4 oz. per square yard. The usual practice is about 3½ oz. per square yard. Four coats of dope and the finishing varnish weigh about 4 oz. per square yard, bringing the total weight of doped fabric to about 7 oz. per square yard.

Attachment to the Planes.—The fabric is fairly tightly stretched over and attached to the wing ribs, which maintain the true shape of the wing.

Apparently there is a difference of opinion as to whether the fabric should be laid on diagonally or straight. The former method is supposed to give the greater strength, and is the principle adopted in the construction of motor car tyres. In any case the fabric when put on should not be too tightly stretched. A uniform or even tightness throughout is of far more importance than irregular though higher tensions.

Various methods are adopted for attaching the fabric to the planes. On most modern aeroplanes the fabric is sewn with needle and thread, with kite cord knotted along each rib through the plane to the opposite side, and on each turn. The pitch of the stitches over the ribs should not exceed 3 in., and in small scout machines, 2 in. No. 40 3-cord linen sewing thread is usually employed, eight stitches per inch. Neither the kite cord nor the thread should be waxed, as wax affects the dope. Where any fabric is laced into

The United States Army specifications call for a heavy linen tape between the heads of the outside tacks and the fabric. The width of the tape is from $\frac{3}{4}$ to $1\frac{1}{2}$ in., and the edges are frayed about $\frac{1}{4}$ in. This fraying is intended to make a good joint between the tape and fabric when the wing is subsequently doped.

(c) The dilutents (colloquially, diluents or thinners). Benzol,

ethyl alcohol and methyl alcohol are added to make the solution less viscous and more easily applied. It may be noted that benzol when added in excess tends to make the film brittle.

(d) Plasticisers (colloquially, softeners or high boilers). A plasticiser is a solvent with a comparatively high boiling point. It is thus a material which evaporates very slowly from the film, and therefore, the latter is rendered pliable and slightly elastic, and so enables it to withstand the stress of daily work. The plasticisers which are utilised for cellulose acetate are benzyl alcohol, benzyl benzoate, benzyl acetate and triacetin and diacetone alcohol. For cellulose nitrate dope, castor-oil is often used as a non-solvent softener. Triphenyl phosphate is also employed; though it has certain disadvantages, it is useful, as it is a fireproofing agent. A little urea is occasionally added, to neutralise any acidity existing in the dope, or developed therein when acted upon by light. The object of these plasticisers is to avoid whitening or blushing of the film, due to the action of moisture in precipitating out the cellulose acetate or nitrate. The action of the plasticisers is to re-dissolve these celluloses.

The tensile strength of the fabric is increased by application of dope. However, the tear resistance is slightly decreased, this being dependent to the extent of the penetration of the dope into the fabric. From this it will be appreciated that the tear resistance of a coarsely woven fabric is considerably lowered.

As all dopes are more or less affected by sunlight, they should be protected by covering them with a suitable non-actinic pigment. If a pigment similar to that known as P.C. 10 can be obtained, no varnish is necessary. Incidentally, this particular pigment dries flat (which diminishes the reflection and flashing of an aeroplane in the sun or under the rays of a searchlight). When P.C. 10 pigment is not available, a pigmented oil varnish, the base of which is China wood oil, is often substituted. The pigment or varnish is also put over the dope film to protect it from water vapour, to which it is pervious. Varnishes must, of course, be of the waterproof type.

There are practically three classes of varnish—(1) with spirit basis, (2) with oil basis, (3) a combination of both.

The spirit varnishes consist of dissolved resins, such as shellac, in alcohol or methylated spirit. The setting of this class of varnish is dependent upon the rapid evaporation of the solvent, which leaves the resinous substance behind.

Oil varnishes are composed of drying oils, such as linseed, walnut, China wood oil, and poppy, which readily oxidise when exposed to the air in thin films. To accelerate the oxidation the oils are treated beforehand by boiling, or by the addition of certain chemicals. This class of varnish takes longer to set than a spirit varnish.

In the third class, oils, resins, and turpentine and similar constituents are blended together.

Spirit varnishes are more suitable than oil varnishes for aeroplane

work, as the latter, in spite of giving a durable and elastic coating, tend to crack too readily and destroy the fabric. Oil varnishes contain vegetable drying oils, and take from 1 to 3 days to harden. In hot weather oxidation of the drying oils takes place very rapidly, and cracks quickly appear. An oil varnish will frequently crack and peel off, taking the dope film with it. Spirit varnishes, on the other hand, do not undergo this quick change, nor do they destroy the fabric; also they retain their pliancy for a considerable time, hence their superiority over oil varnishes.

The total increase of the weight of the fabric, when doped, etc., should be about 2 oz. to 2.75 oz. per square yard. Various cellulose acetates have a similar composition, but when dissolved the viscosities are not alike; however, tautness is independent of the viscosity. Further, tautness is independent of the degree of stretching of the original fabric, though it is largely affected by light by the count of the fabric, also the twist and closeness of the weave. Instruments are available for measuring tautness, and are known as tautometers.

The paint pots used as containers for the dope should be of the chicken-feed pattern, as this exposes the minimum amount of surface of the material to the atmosphere, thus the evaporation of solvents and consequent change in viscosity and loss of material, is reduced to a minimum.

The preliminary coating should be well brushed in with stiff brushes, then thoroughly dried out, and well rubbed down with pieces of old undoped fabric.

Great care must be exercised in the application of the subsequent coats of dope and varnish. The stuff must be laid on evenly and thinly, care being taken not to do any more brush work than is absolutely necessary, or the surface will be spoiled. Special brushes (2 to 4 in. wide) must be used, or loose hairs will spoil the surface. Fabric should always be stretched as evenly as practicable before coating, instead of relying upon the coating material to take up the slack. The reason for this is two-fold. First, the fabric would sag if the coating gave way; and secondly, a greater weight of fabric and coating material would be needed. If the fabric is well tightened when first laid in place, more flexible, and therefore longer lived, coating materials can be employed.

All coating or repair work should be carried out in an atmosphere free of dust, otherwise the dust particles will form starting-points for the disintegration of the surface.

Care must be taken not to overdope a plane, as a proportion of the dope will accumulate on the underside of the fabric, where it will decompose and destroy the fabric. On no account should sandpaper or other abrasive material be employed. Upon the amount of good work put into this first coating depends the final result, hence it is of the utmost importance that every precaution should be taken to ensure high-class work. The dope should only be applied in a room the temperature of which is between

Any oil or grease spots that may accidentally get on to the fabric while doping, should be removed by the use of benzol, working round from the outside of the spot, towards the centre. If an oil spot is not removed, any dope which comes over it, is liable to blister or form bubbles.

ARMAMENT OF AEROPLANES

1. (a) Fighters.
(b) Fighting scouts.
2. Ground attack or trench fighters.
3. Reconnaissance and artillery observation aeroplanes.
4. Day bombers.
(a) Short distance.
(b) Long distance.
5. Night bombers.
(a) Short distance.
(b) Long distance.

Two-seater fighters are usually provided with one or more guns mounted on ring or other types of gun mounts. These guns are

operated by the passenger or passengers. Fighting scouts are, almost without exception, single-seaters, and their equipment therefore usually consists of two forward machine guns only.

2. The armament equipment of **Ground Attackers or Trench Fighters** is similar to that of fighters, with the addition that they are often protected by armour plate.

3. **Reconnaissance and Artillery Observation Aeroplanes** are usually two-seaters. Their normal equipment is one forward gun firing through the airscrew, and another gun for operation by the passenger attached to a ring or other type of gun mount. In addition, these aeroplanes are equipped with a camera, wireless instruments, and pyrotechnic signalling devices.

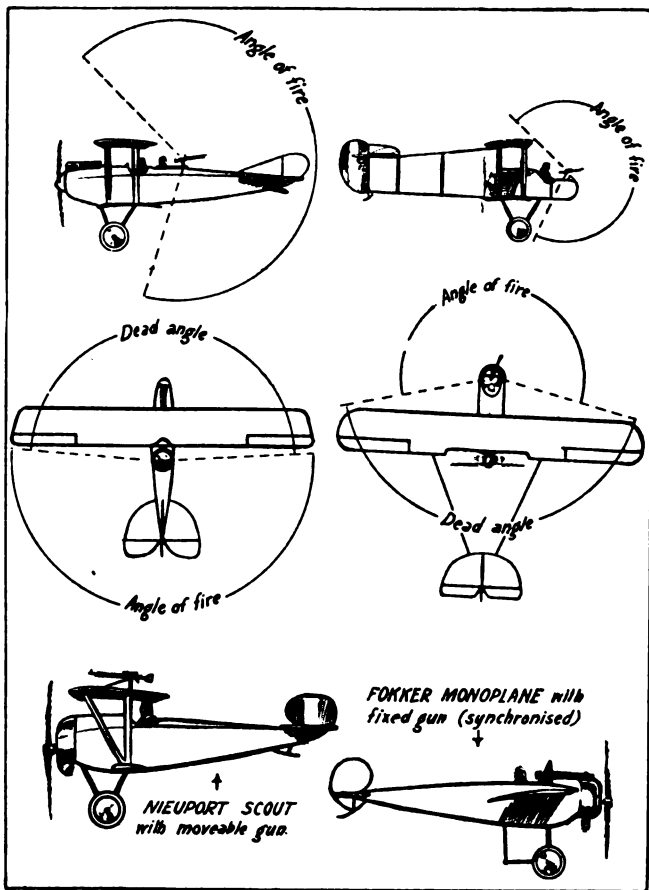
4. **Day Bombers** are generally fitted with one forward gun, and as their name implies, are loaded up to their maximum capacity with bombs.

5. **Night Bombers** are similarly equipped to the day bombers, but in addition have arrangements for carrying navigation and landing lights, signals, etc.

The position selected for the guns is naturally of great importance, as it is so essential to avoid what are known as blind spots. By the term, "blind spot," is meant a position which can be taken up by enemy aircraft, without the possibility of its being hit by the firing from the aeroplane it is pursuing.

Gun positions of some of the early aeroplanes are indicated in the diagrams herewith, viz., Aviatik 1915 Tractor, Maurice Farman Pusher, Nieuport Scout, and Fokker Monoplane.

In the early days of the war, pusher biplanes were considered to be the best for fighting, owing to the possibility of a big forward angle of fire, and they held their own, until the Nieuport tractor scout came into the field fitted with fixed machine gun, mounted above the top plane, so as to fire above the airscrew. As is well known, the tractor aeroplane has greatly improved manœuvring powers as compared with the pusher, and hence this innovation was very valuable. The particular mounting of the gun referred to, however, means a greatly increased head resistance for this type of aeroplane, and further, there was the great difficulty of having to pivot the gun down for replenishing the ammunition. The next improvement, which is associated with the name of Garros the French pilot who was the first to employ the system, was to fit hard steel deflectors on the airscrew blades, and then fire the machine gun through the airscrew. It was found that the number of bullets which slipped off and were lost amounted to less than 8 per cent. Though this loss is not very great there was the further objection, that the speed of the aeroplane was reduced by about 12 miles (20 km.) per hour owing to the loss of efficiency of the airscrew when fitted with these deflectors. In 1915, synchronous gears operated by the engine were employed, and they are now the standard method. In the earlier German aeroplanes fitted in this way, the firing of the gun was controlled by rigid gear (e.g., Fokker,



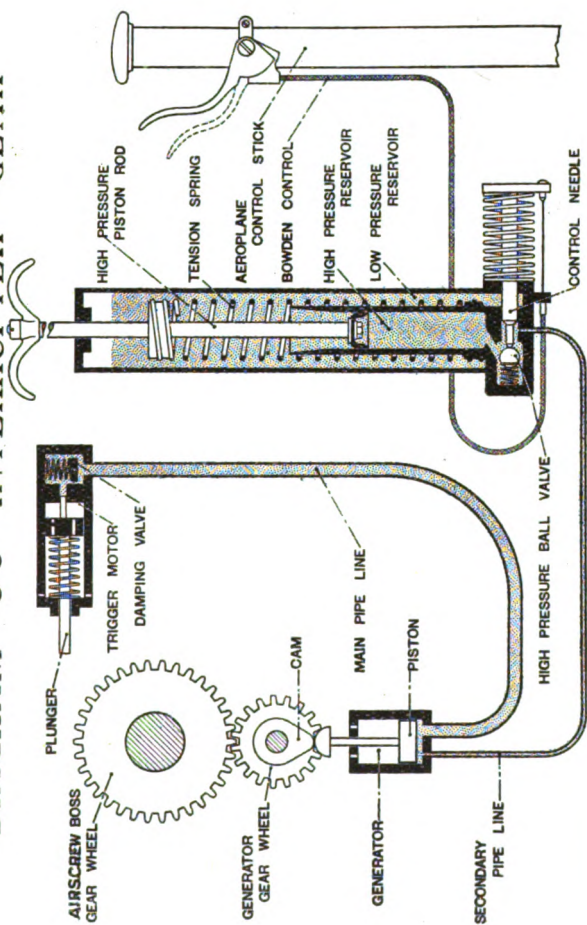
Gun Positions on Aviatik 1915 Tractor, Maurice Farman Pusher, Nieuport Scout, and Fokker Monoplane.

D.L.D. 4 (Detachable Lufas System)
R. B. L. M. Matheson. Patents (personally protected) U.S. Patents applied for.

DIAGRAM C.C. INTERRUPT GEAR

ARMAMENT

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Halberstadt, etc.). A later form was the flexible gear (used in Rumpler C. and other German aeroplanes). In all cases, the pilot starts and stops the firing through the medium of a bowden wire connected to a lever on his control column.

An oil wave transmission gear, known as the Constantinesco (or briefly C. C. Gear), is chiefly employed by the Allies. In this system, oil in a pipe line serves as a medium for conveying motion from the engine to the machine gun. A piston suitably mounted is caused to vibrate against the revolving cam on the engine or the airscrew shaft. This piston is connected through the oil pipe system to another piston mounted on the machine gun itself. The outer extremity of this latter piston is arranged to operate the machine gun lever or trigger at each outward movement. The required pressure in the oil pipe system is introduced by means of a suitable reservoir, and the operation is controlled by a valve chamber and control lever. The diagram on the previous page illustrates the principle of operation.

When it is desired to operate the machine gun the control lever is depressed, this operates the valve and introduces pressure throughout the system, the piston at the cam is forced into contact, and vibrates. The vibrations are transmitted through the oil in the pipe line, to the piston of the trigger motor on the gun. The outer extremity of the trigger motor piston trips the trigger of the Vickers' gun. To stop firing, the lever is released; this closes the high pressure valve and opens the low (or no pressure) valve. The result of this is that the pressure falls, and the generator piston is no longer in contact with the cam, hence the vibrations cease.

Other types of interrupter or synchronised gun gear are as follows:—

Vickers.—The drive from the engine actuates a cam which gives motion to links and levers operating the lever trigger bar of the Vickers' gun.

Sopwith-Kauper.—An arrangement of links and levers operated from a cam on the engine shaft and actuating the trigger of the Vickers' gun.

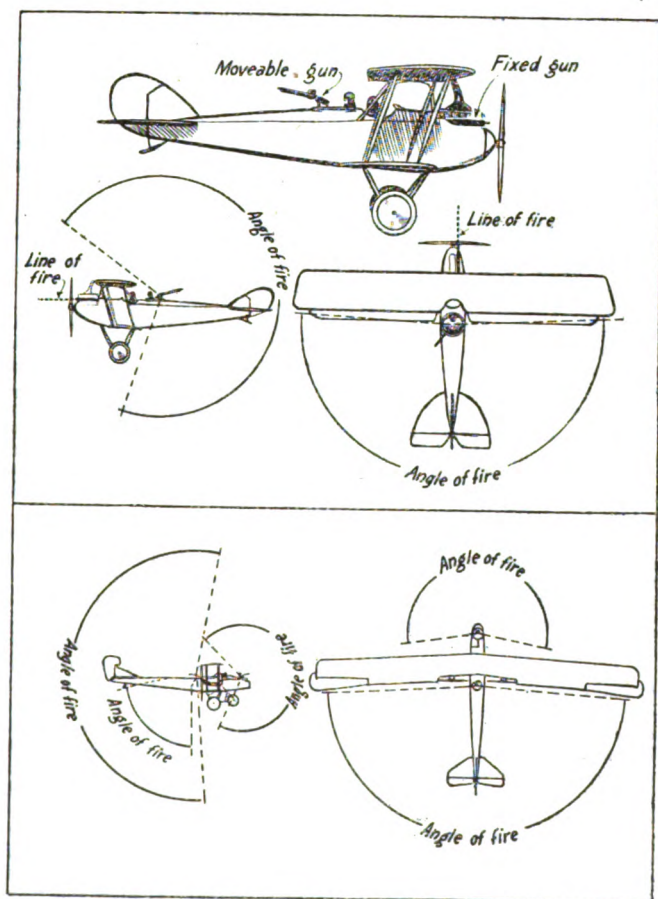
Scarff.—A simple link and lever arrangement, and the forerunner of the Sopwith-Kauper.

Spad.—This is particular to aeroplanes fitted with Hispano-Suiza engines. The drive is from the engine direct, and operates through a cam and rocking shaft the trigger of the Vickers' gun.

German Flexible Drive.—The title of this is self-descriptive.

Arrangement of Guns.—The most general arrangement of machine guns on fighters is shown in the diagrams herewith.

Amongst the aeroplanes that follow this system are the Albatros, Aviatik, L.V.G., Rumpler, etc. Amongst British aeroplanes,



Arrangement of Guns on Modern Aeroplanes.

which adopt this arrangement, those which are perhaps best known, are the Bristol Fighter and De Havilland 4.

A later development is in the case of multi-airscrew aeroplanes which permit of the mounting of the forward gun on the ordinary type of adjustable gun mount. As the multi-airscrew aeroplane is naturally a big machine, it affords an opportunity for placing an additional gun in such a position as to fire through a trap or tunnel downwards and backwards through the floor of the fuselage, thus affording protection for what would otherwise be a blind spot.

Gun Mounts and Auxiliaries.—Machine guns which are mounted so as to fire between the blades of the revolving airscrew are usually fixed to the fuselage, and therefore permit of no variations in their position once they are aligned. Ammunition is fed to these guns in the standard type of canvas belt, as employed on the field pattern of the Vickers' machine gun, or by aid of the field type of disintegrating link pattern belt. The latter type of belt appears to be the most convenient for aircraft purposes, since the belt breaks up after a cartridge is extracted, and then the empty links and cases can fall away through the chutes provided. The ammunition belt, whether it be of the canvas, or link type, is stored in a suitable magazine, and passes through a guide roller to the feed block automatically as required. When a canvas belt is employed, another magazine has to be provided for the empty belt.

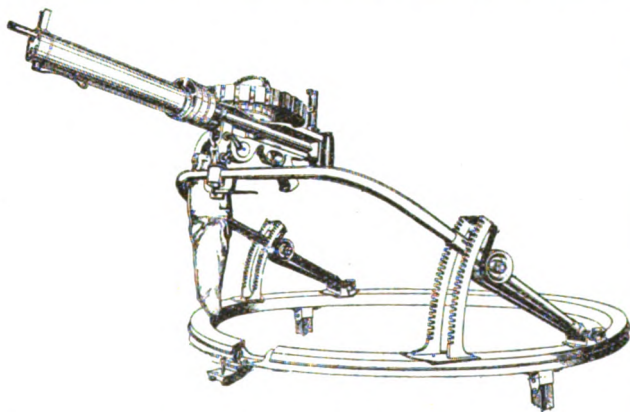
In the case of aeroplanes which are fitted with two machine guns all such magazines and chutes must be duplicated. Further, it is usually more convenient to provide them with right and left-hand feed blocks. For convenience also in fitting, one gun is often placed a few inches further forward than the other.

Two types of sights are fitted as a rule, (a) ring and bead and (b) optical sight. Illuminated sights are fitted for night use. Certain aeroplanes which have to be operated at exceptionally high altitudes, have to have the machine guns fitted with electric heaters. These are supplied with current from airscrew-driven independent generators or from accumulators placed in a convenient position in the fuselage. These accumulators also supply the current for the electrically heated clothing for the pilot and passengers.

Gun mounts are of a very varied type and design, in order to meet the various demands for fitting guns in different positions. The most common position is in the centre of the fuselage on the top of the longitudinals. Here the most popular type is the ring mount; the Scarff ring, suitable either for one or two Lewis guns, being the one most used. Various modifications on the Scarff ring mount have appeared from time to time, the respective merits of which it is not proposed to discuss. Guns fitted on this form of mount are, almost without exception, operated by the

passenger or gunner on an aeroplane. Another type is the pillar mount, and this, like the ring, has several modifications. Briefly, it may be described as either a fixed, hinged, or movable pillar. It is fitted with the necessary clips for securing it in a particular position, and it is further provided with a socket for the reception of a pin, incorporated with the yoke to which the gun (usually a Lewis) is attached.

Another type is the top plane mount. This is usually arranged to fire in the direction of flight, the bullet passing clear of the airscrew tips. The loading of the magazine is the greatest disadvantage in connection with this particular type of gun mount, and mainly on that account, the Lewis gun is the only one at present used on such mounts. On loading the gun, it is released



from its sockets, and hinged down so as to be within easy reach of the pilot (who usually operates such guns) for the removal of the empty, and the fitting of a full drum. Still another type of mounting, which is very varied in design, is the one arranged to fire underneath the aeroplane. This is fitted to the bottom of the fuselage, hinged doors being provided, through which the barrel of the gun protrudes when in use. In this respect not only Lewis, but guns of heavier calibre have been used, and in this direction great developments will probably take place.

Armour plating usually comprises the provision of suitable bracket plates for the pilot, engine and tanks, since these are considered the most vital parts of the aeroplane. This plating, when used, is generally located on the sides and underneath the fuselage, but the number of aeroplanes in the British service so

fitted is exceedingly small; only aeroplanes which may be subjected to concentrated fire from infantry being so fitted.

Bombs and Bomb Gear.—Bombs are fitted either inside or underneath the fuselage, or underneath the main planes. In each case, release mechanism and safety devices are provided, for the prevention of premature fusing. The number of types of release are legion, although very few are really efficient and can be depended upon without constant attention. The fitting of bombs inside the fuselage is probably the most efficient method of stowage from the point of view of the necessity for diminishing head resistance, although for the actual placing of the bombs in the carriers, it is the most troublesome plan. When stowed in this manner, bombs are usually held nose or tail down, and when released drop through the cells in which they are contained. In their descent, they open hinged metal doors at the bottom of the cells, and are then clear of the aeroplane. When fitted underneath the fuselage or main planes, they are suspended by means of a carrier, and lie in a horizontal plane, nose forward. The release of bombs is usually carried out by means of a lever or other convenient device, in some instances operated by the pilot, and in others by the passenger.

Bomb Sights.—In the early days of the aeroplane warfare, many bombs were thrown out of the machine by hand in an indiscriminate manner: nowadays, bombing is a matter of great precision. Bomb sights are numerous and varied, and at the present time a number of most efficient sights exist. Allowances for the speed of the aeroplane, the direction and the velocity of the wind, and the height, have to be taken into account, and readings on the target made accordingly; then the release lever for the bomb is operated at the precise moment. Even with such highly efficient instruments, the human factor has to be considered, and bombing is a science which has to be carefully studied and practised by the aviator whose duty it is to carry out such work, before high efficiency is possible.

DE-DA (Detachable Data) System
R. Barlow Matthews' Patents (provisionally protected) U.S. Patents applied for.

GLOSSARY OF AERONAUTICAL TERMS

By kind permission of the Royal Aeronautical Society, the definitions of Aeronautical Technical Terms as issued by them in 1914 are now incorporated in this division. The Technical Terms Committee (of which the author is now a member) has now nearly completed an extension of this list of definitions, and the Secretary of the Aeronautical Society would be pleased to receive suggestions from the readers of this Pocket-Book. In the meantime, unofficial terms are incorporated to make this glossary more complete. Official terms are designated by an asterisk.

The two folding plates in this "Aviation Pocket-Book" will be found of assistance if referred to in conjunction with this glossary.

It had been intended, but time did not permit, to classify the whole of this glossary in accordance with the Decimal Classification System. That is by the method which has been adopted for the whole of the "Aviation Pocket-Book," for the first time, in the present edition. The new definitions of the Royal Aeronautical Society, which are now in the Press, will also be so classified. This is another reason for not attempting to modify the present arrangement, as such an authoritative publication will be ready so shortly.

A novel feature of the glossary this year is, that a number of the terms are translated into French, for the purpose of assisting those who have occasion to refer to French literature.

Aero [*aérien-enne* (a.)].—Appertaining to the air. **Aerial**.

Aerocurve.—Any curved supporting surface. **An aerofoil**.

Aerodrome [*aérodrome* (m.)].—The popular name given to a ground used for the practice of flight. Literally this would mean an "air runner" or flying machine of any kind. Sometimes used to describe power-propelled flying appliances only.

Aerodynamics [*aérodynamique* (f.)].—The science relating to the effects produced by air in motion.

Aerofoil [*aile* (f.) *d'aéro*].—A structure, analogous to the wing of a bird, designed to obtain a reaction from the air approximately at right angles to the direction of its motion.

Aerometer.—An instrument for determining the density of the atmosphere.

- Aéronat.**—An airship or dirigible balloon.
- Aeronaut** [*aéronaute* (m.)].—The pilot of a balloon.
- Aeronautics** [*aéronautique*].—The entire science of aerial navigation.
- Aeronef** [*aéronef*].—Any self-propelled steerable aerial appliance.
- Aeroplane** [*aéroplane* (m.), *avion* (m.) = military aeroplane].—Commonly any heavier-than-air craft with fixed wings, and driven as opposed to an airship which is lighter than air.
- Aerostat** [*aérostât* (m.)].—An appliance which is sustained in the air through the medium of a gas lighter than air. The gas-bag itself.
- Aerostatics** [*science (f.) de l'aérostation*].—The science relating to the effects produced by buoyancy in air by means of displacement. The study of the mechanical effects produced by air at rest.
- Aerostation** [*aérostation*].—The navigation of the air by lighter-than-air machines, dirigibles, or balloons.
- Aileron** [*aileron* (m.)].—Aerofoils used for causing an aeroplane to roll about its longitudinal axis for the purpose of balancing.*
- Aircraft** [*aéronef* (m.)].—A generic term for all types of air-supported vehicles.
- Air Lag.**—The horizontal distance at any height between the vacuum flight-path and the real flight-path of a body.
- Air Pocket** [*trou* (m.) *d'air*].—A local movement or condition of the air. This is due to vertical or to downward currents. On entering a pocket, the reaction on the supporting planes of an aeroplane is reduced, and the aeroplane drops until the increased velocity due to its loss of height is sufficient to restore the normal reaction. *Aremou.*
- Airscrew** [*hélice* (f.)].—Used as a generic term to include both a propeller and a tractor screw. See "Screw." A slang term is "wind stick."
- Airscrew Boss** [*moyeu* (m.)].—The central portion of an airscrew.
- Airscrew Hub** [*moyeu* (m.) *d'hélice*].—The part over which the boss fits, which takes the torsional drive. It is sometimes known as the nave, loose hub, rear flange, or back plate.
- Airscrew Hub Flange** [*contre-bride d'hélice* (f.)].—A flange or plate, generally loose or separate, fitted in front of the airscrew boss to take the pull of the bolts from the airscrew hub. Sometimes called a nave plate, airscrew plate, or front flange.
- Airscrew Slip** [*recul* (m.) *d'hélice*].—The ratio of the difference between the speed of advance of an aircraft to the speed of the advance necessary for a zero thrust.
- Airship** [*dirigeable* (m.)].—A dirigible balloon or aeronat.

Air Speed [*vitesse* (f.) *par rapport à l'air*].—The velocity of the aircraft relative to the air in which it moves.

Air Speed Indicator [*indicateur* (m.) *de vitesse* (f.) *rotative*].—A velometer. An instrument for measuring speed relative to the surrounding air, usually constructed in the form of a Pitot tube actuating a liquid gauge or a diaphragm indicator.

Alight, To [on land, *atterrir*; on the sea, *amerrir*].

Alighting Carriage [*train d'atterrissage* (m.)].—A colloquial term; should be called "Undercarriage." That part of the aircraft beneath the body intended for its support on land or water, and to absorb the shock of alighting.*

Altimeter [*altimètre* (m.)].—An instrument devised to indicate the height of an aircraft above sea level.

Anemodograph [*anémographe*].—An instrument for recording the direction of the wind.

Anemometer [*anémomètre* (m.)].—An instrument for measuring the speed of the wind.

Angle, Dihedral [*vue* (m.) *transversal*].—In geometry, the angle between two planes. The wings of an aeroplane are said to be at a dihedral angle when both right and left wings are upwardly or downwardly inclined to a horizontal transverse line. The angle is measured by the inclination of each wing to the horizontal. If the inclination is upward, the angle is said to be positive; if downward, negative.*

Angle, Gliding [*angle vol* (m.) *plane*].—The angle between the horizontal and the path along which an aeroplane, in ordinary flying attitude, descends in still air when the airscrew is giving no thrust.

Angle of Attack [*angle* (m.) *d'attaque* (m.)].—An alternative term for angle of incidence.

Angle of Bank [*angle de gaudrissement*].—The angle through which the aircraft must be turned about the longitudinal axis, whether horizontal or inclined, to bring the lateral axis to a horizontal position. As a common case in horizontal normal flight, the angle of bank is the angle of inclination to the horizontal of the line joining the wing tips.

Angle of Incidence [*angle* (m.) *d'incidence*].—When rigging an aeroplane the term angle of incidence is sometimes used to describe the angle between a chord and some fixed plane in relation to the machine.

Angle of Incidence or Angle of Attack [*angle* (m.) *d'incidence*, ou *angle* (m.) *d'attaque* (m.)].—The angle a wing makes with the direction of its motion relative to the air. The angle is usually measured between the chord of the wing and the direction of motion.

- Angle of Incidence, Maximum** [*angle d'incidence maximum, etc.*].—The greatest angle of incidence at which, in a given machine, horizontal flight can be maintained.
- Angle of Incidence, Minimum**.—The smallest angle of incidence at which horizontal flight can be maintained.
- Angle of Incidence, Optimum**.—The angle of incidence giving the maximum lift-drag ratio.
- Angle of Pitch** [*angle (m.) d'écartement (m.)*].—The angle between the plane containing the lateral axis and the direction of the relative wind and the plane containing the lateral and longitudinal axes. As a common case, in horizontal normal flight the angle of pitch is the angle between the longitudinal axis of the aircraft and the direction of the relative wind. *Cf.* "Axis."
- Angle of Stagger** [*angle (m.) de dévalage (m.)*].—The angle which the normal axis of the aeroplane makes with a line locating points in the leading edges of the wings and parallel to the plane of symmetry of the aeroplane.
- Angle of Sweepback**.—The angle made by the main planes in a horizontal plane with a horizontal line at right angles to the left of the machine.
- Angle of Trail** [*angle (m.) de traînée (f.)*].—The angle made between the trailing edge and the chord.
- Angle of Yaw** [*angle (m.) de lacet (m.)*].—The inclination of the direction of the relative wind to the plane of symmetry of the aircraft.
- Anti-Cyclone** [*anti-cyclone (m.)*].—The reverse of a cyclone. Wind blowing in a clockwise direction around a centre of high pressure, from which the pressure falls slightly on all sides. It has no general direction of motion. Weather fine on whole.
- Anti-Drag Wires**.—Wires strained in the opposite direction to the drag wires to keep the latter taut. Also to assist in keeping the wing in its proper attitude relative to the fuselage or body.
- Anti-Lift or Landing Wires** [*haubans supérieurs (m.) d'atterrissage (m.)*].—The wires used to resist forces in the opposite direction to the lift. Also employed to take the weight of the wings when the aeroplane is resting on the ground, and to take up landing stresses.
- Anti- or Counter-Warp Wires**.—Compensating wires used to take the weight of the rear wing spar when on the ground. They are connected across from wing to wing, transmitting the warping action from one to the other.
- Apteroid Aspect** [*prime (f.) aptère*].—The converse of pterygoid aspect, *i.e.*, with the greater dimension arranged in the direction of flight. End-on aspect.

Arched [*courbe*].—Curved as viewed from the front (of an aerofoil).

Atterissage [*atterrissage* (m.)].—The landing.

Attitude [*attitude* (f.)].—An aeroplane's or plane's position relative to the direction of motion through the air.*

Attitude Relative to Ground [*attitude par rapport à la terre*].—The attitude of an aeroplane is determined by the inclination of its three principal axes to the ground.

Attitude Relative to Wind [*attitude par rapport au vent*].—The attitude of an aeroplane is determined by the inclination of its three principal axes to the relative wind.

Aspect Ratio [*allongement*].—The ratio of the length of the span to the width of the chord of an aerofoil. When this ratio is greater than unity the planes are in pterygoid, or broadside aspect. When less than unity they are said to be in apteroid, or end-on aspect. In modern machines the broadside aspect is usually employed, the aspect ratio being from about 4 to 8.

Aviation [*aviation* (f.)].—The art of flying as distinct from ballooning.

Aviator [*aviateur* (m.)].—The pilot or driver of an aeroplane.

Avion [*avion* (m.)].—Official French term for a military aeroplane only.

Axes of an Aircraft [*axes* (m.) *d'un aéronef* (m.)].—Three lines of reference passing through the centre of gravity and mutually rectangular. Two systems of axes are commonly only used.

Axis, Cross-Wind [*axe* (m.) *de contre vent*].—A line in the plane of symmetry through the C.G., which is perpendicular both to the plane of symmetry and to the direction of the wind.

Axis Drag [*axe* (m.) *de résistance* (f.) *à l'avancement* (m.)].—A line in the aeroplane or airship which passes through the C.G. and is parallel to the direction of the relative wind.

Axis, Lateral [*axe latéral levant*].—A line through the C.G. normal to the plane of symmetry of the aeroplane or airship. In an aeroplane the lateral axis is conveniently taken parallel to a line joining the wing tips, and when looking in the direction of motion of the aircraft the positive branch of the axis is to the left.

Axis Lift [*axe* (m.)].—A line in the aeroplane or airship which passes through the C.G., is in the plane of symmetry, and is perpendicular to the relative wind.

Axis, Longitudinal [*axe longitudinal*].—A line in the plane of symmetry of an aeroplane or airship through the C.G., fore and aft. For the purposes of general discussion this axis can be taken at a parallel to the airscrew axis. The positive direction to be taken backwards from the C.G.

Axis, Normal [*axe* (m.) *normal*].—A line in the plane of symmetry up and down and through the C.G. with the longitudinal and lateral axes horizontal, the normal axis is vertical, and the positive direction is upwards in all aircraft.

B.A.—British Association standard screw threads (for bolts of $\frac{1}{8}$ in. to $\frac{1}{2}$ in.).

Back, To [*changement de direction centre solaire (du vent)*].—Of the wind, to change direction counter-sunwise (counter-clock-wise).*

Balancing Flaps [*ailerons* (m.)].—A colloquial term. Aerofoils used for causing an aeroplane to roll about its longitudinal axis for the purpose of balancing. See "Aileron."

Ballonet [*ballonet*].—A word taken from the French, meaning "a little balloon," and limited to an interior bag containing air, within the envelope of an airship.*

Bank, To [*virer penché*].—To heel for the purpose of turning.* To put one plane tip higher than the other. Cf. "Roll."

Barograph [*barographe* (m.)].—A recording or self-registering barometer, which can be calibrated to indicate pressure or height above sea level.

Barometer [*baromètre* (m.)].—An instrument employed for measuring the pressure of the atmosphere. There are two principal types: (i.) the mercury column, and (ii.) the aneroid or vacuum.

Bay [*casse* (f.) *traverse* (f.)].—In any girder construction the space enclosed by two vertical struts and the horizontal members to which they are attached.

Biplane [*biplan* (m.)].—A heavier-than-air flying machine, the general feature of whose construction is two superposed parallel aerofoils, planes, or supporting surfaces, or any system of two superimposed aerofoils.

Body [*fuselage* (f.)].—A colloquial term; should be "fuselage" of an aeroplane—that part which usually contains the engine, crew, tanks, etc., and to which the wings, undercarriage, and other organs are attached.*

Boom, Tail.—A long spar joining the tail of a pusher machine to its main planes.

Bracing [*haubannage* (m.)].—A system of struts and ties to transfer a force from one point to another.*

B.S.F.—British Standard fine screw threads for bolts of $\frac{1}{8}$ in. to $\frac{1}{2}$ in.

Buoyancy [*lévité* (f.) *élasticité*].—The property by which a balloon remains floating in the air. Relative displacements.

Burble [*condition critique*].—The unstable condition of air flow about an aerofoil, in which the lift component rapidly decreases with increase of angle of incidence and the drag component rapidly increases. Sometimes referred to as the "breakdown" of the aerofoil.

Burble Point or Critical Angle [*angle critique*].—That point on the lift curve of a wing which is reached when the angle of incidence or inclination has so increased that the stream lines change from a steady to a fluctuating and eddying state, causing the lift to fall and the drift to increase.

Cabane [*cabane* (f.)].—A French word to denote the mast structure projecting above the body to which the top load wires of a monoplane are attached.*

Cables [*cables* (m.), *haubans* (m.)].—Several single wires stranded together to provide greater flexibility than the equivalent solid wire.

Cabré [*cabré*].—Tail down.*

Camber [*courbure* (f.)] (of a wing section).—The convexity of a wing section. The camber is usually measured (as a fraction of the chord) by the maximum height above the chord.*

Camouflage [*camouflage* (m.)].—Strategical protective colouring.

Cant, To [*incliner ou pencher ou cabrioler*].—To tilt; to take any inclined position.* *

Carburettor [*carburateur* (m.)].—The device on an internal combustion engine using liquid fuel, employed for vaporising that fuel and mixing it with the proper proportion of air.

Carlingue [*carlingue* (f.)].—The foundation of a nacelle.

Carriage [*train d'atterrissage* (m.)].—A colloquial term; should be "undercarriage." That part of the aircraft beneath the body intended for its support on land or water, and to absorb the shock of alighting.*

Ceiling [*plafond*].—The maximum height to which an aeroplane can climb. See limiting height.

Cellule [*cellule* (f.)].—The box-like rectangular compartments in a biplane formed by the planes and vertical struts.

Centre of Gravity [*c.d.g., centre* (m.) *de gravité*].—That virtual point at which the weight of the body may be supposed to act, and about which, if supported, the body would rest in any position, *i.e.*, balance.

Centre of Pressure of an Aerofoil [*centre* (m.) *de pression d'une aile d'aéro*].—The point on the chord of an element of an aerofoil, prolonged if necessary, through which at any instant the line of action of the resultant air force passes.

Centre of Resistance [*centre (m.) de résistance passive*].—That point at which the resultant head resistance of an aeroplane may be assumed to act in and opposite to the direction of flight.

Centre of Thrust [*axe (m.) de l'hélice*].—That point at which may be presumed to result the total thrust of the airscrew in and along the direction of flight.

Centre Plane, Main [*plan central*].—The portion between two main planes of an aeroplane. Sometimes called a centre section. In a tractor that part of the structure to which the main planes are attached.

Chassis [*train d'atterrissage (m.)*].—An inaccurate term; should be "undercarriage." That part of the aircraft beneath the body intended for its support on land or water and to absorb the shock of alighting.*

Chord [*corde (f.) de l'aile (f.)*].—The straight line (taken conventionally fore and aft unless otherwise specified) touching the under surface of an aerofoil at or near the leading and trailing edges. The length of the chord is the projected length of the section on the chord.*

Climb, Rate of [*vitesse (f.) ascensionnelle*].—The vertical velocity of an aircraft.

Clinometer [*clinomètre (m.)*].—An instrument for measuring the angle of slope of an aircraft, referred to the horizontal.*

Cloche [*cloche (f.)*].—A bell-shaped piece of metal forming part of the control lever on a Blériot aeroplane, and hence sometimes incorrectly employed to describe a control lever.

Cockpit [*nacelle (f.)*].—The portion of a fuselage designed to accommodate pilot and passengers.

Compensating Wires [*haubans (m.) correcteurs*].—Anti-warp wires used to take the weight of the rear main plane spar when on the ground. They are connected across from plane to plane, so as to allow the planes to warp.

Connecting Rods [*bielles (f.)*] for Engines—

Main Connecting Rods [*principales*] are the rods that take the main crankpin pressure.

Auxiliary Connecting Rods [*auxiliaires*] are rods other than the main connecting rods. They are usually attached to wrist-pins on the latter.

An Articulated Rod [*articulée*] is an assemblage of connecting rods.

Consumption per B.H.P. Hour [*consommation* (f.) *par HP. heure*].—The quantity of fuel and oil consumed during one hour by an engine running at normal revolutions and developing normal horse-power at ground level divided by the brake-horse-power developed, unless the context specifically states otherwise.

Control Column [*levier* (m.) *de commande*, *manche* (m.) *à balai*].—On an aeroplane, the device by means of which the principal controls are worked. It usually controls pitching and rolling.* Sometimes called a control lever, or in slang a "joystick."

Cowling [*refroidisseur capotage* (m.)].—A sheet-metal casing or funnel, designed to direct cooling air on to the cylinders of an aero-engine. Colloquially a sheet-metal casing for an engine or radiator.

Critical Angle of Incidence [*angle d'incidence critique*].—The angle of incidence at which the lift coefficient is a maximum.

Critical Angle or Burble Point [*angle critique* (m.)].—That point on the lift curve of a plane which is reached when the angle of incidence or inclination has so increased that the streamlines change from a steady to a fluctuating and eddying state, causing the lift to fall and the drag to increase.

Cross Section [*coupe* (f.) (*d'une aile d'aéro*)] (of an aerofoil).—The section cut by a fore-and-aft plane normal to the surface (commonly the under surface).*

Cross-Wind Axis [*axe* (m.) *contre-vent*].—A straight line in an aircraft passing through the centre of gravity and perpendicular to the lift and drag axes.

Cross-Wind Force [*force* (f.) *contre-vent*].—The component of the force along the cross-wind axis due to the relative wind.

Curtains [*cloisons* (m.)].—The vertical panels or planes placed vertically between the planes of a biplane or the tail thereof, so as to give it a cellular or box-like construction.

Cyclone [*cyclone* (m.)].—Wind blowing in an anti-clockwise direction around a centre of low pressure, from which the pressure rises on all sides. The reverse of an anti-cyclone. Motion as a rule from west to east. Weather wet and rough as a rule.

Damping Factor [*facteur d'amortissement* (m.)].—A measure of the rate of reduction of the amplitude of an oscillation or of the magnitude of a subsidence. Negative damping factors have a similar relation to increasing oscillations and divergences.

Decalage [*décalage* (m.) (*des ailes*)].—The difference in the angle of incidence between any two distinct aerofoils on an aeroplane; e.g., the main plane and the tail; or more usually between the chords of the upper and lower planes of a biplane.

Deviation [*déviatiou*].—The error in the indications of a compass due to the proximity of iron fittings, etc., which form a part of the aircraft structure.

Dihedral Angle [*dièdre vee* (m.)].—In geometry, the angle between two planes. The planes of an aeroplane are said to beat a dihedral angle when both right and left planes are upwardly or downwardly inclined to a horizontal transverse line. The angle is measured by the inclination of each plane to the horizontal. If the inclination is upward the angle is said to be positive; if downward, negative.*

Directional Stability [*stabilité de direction*] is said to exist when an aeroplane has a tendency to retain its initial direction of flight.

Dirigible [*dirigeable* (m.)].—A power-driven steerable balloon.

Disturbing Moment [*moment de déranger*].—A moment which tends to produce any rotational disturbance of an aircraft.

Dive [*vol piqué*].—To descend steeply with the nose of the aircraft down.*

Divergence [*divergence* (f.)].—A disturbance which increases without oscillation.

Dope, To [*enduire*].—Of fabrics—to paint a fabric with a fluid substance for the purpose of tightening and protecting it.*

Double-Surfaced [*surface doublée*] (of an aeroplane wing).—Having the upper and lower surfaces made of two distinct layers of fabric, between which lie the spars and ribs of the plane.

Downwash.—The downward deviation of the relative wind after passing the main planes.

Downwash Angle.—The downward deviation of the relative wind after passing the main planes.

Drag [*trainée* (f.)].—The component of the resultant force which acts along the drag axis. The resistance along the line of flight. The head resistance. Cf. "Drift."

Drag Axis [*axe* (m.) *de résistance passive* (f.)].—A straight line in an aircraft which passes through the centre of gravity and is parallel to the direction of the relative wind.

Drift [*aller à la dérive*. *Dérive* (nav.) (f.)].—The distance drifted. The speed of drifting. The word "drift" having a well accepted nautical significance should be avoided as far as possible in the sense of "head resistance" or "drag."* Drifting is motion purely relative to a fixed point.

Dropping Angle [*angle de lance-bombes*].—The angle between the vertical and the line joining the aeroplane to the target at the correct moment for release.

Dry Weight [*poids, sec.*].—The weight of an engine including magnetos, carburettors, and propeller hub, but excluding exhaust manifold, oil, and water.

Elevator [*gouvernail de profondeur* (m.)].—An aerofoil set in a more or less horizontal plane and hinged on an athwartships or transverse line. It is used for controlling the angle of incidence or the pitching of an aeroplane.*

Elevator Control Lever [*levier* (m.) *de commande du gouvernail de profondeur*].—The lever which operates the elevator, sometimes called the elevator cross shaft, or in slang, the "bloater."

Empennage [*empennage* (m.)].—A colloquial term; it should be called a "tail plane," which is a horizontal stabilising surface, mounted at some distance behind the main lifting surfaces. See "Tail Unit."

Engine Bearer Plate [*plateau du moteur*].—The support for a rotary engine.

Engine Bearers [*supports* (m.) *de moteur*].—The parts of the fuselage or nacelle on which the engine is supported.

Entering Edge [*bord* (m.) *d'attaque (de l'aile)*].—An inaccurate term; should be "Leading Edge." Of a plane—the forward edge.*

Envelope [*carène* (f.)].—The covering of the gas-containing part of a balloon.

Equilibrium [*équilibre*].—In connection with aeroplanes this word is used in the same sense as balance; for balloons it means the keeping at a uniform altitude.

Fabric [*entoilage* (m.)].—The covering material for a plane. Usually unbleached linen.

Fairing [*fuselé* (m.)].—A piece added to any structure to reduce its head resistance or drag.*

Fin Post [*poteau de dérive*].—The rear vertical post of the fin. The rudder, or a part thereof, is often attached to this post.

Fins [*plan de dérive* (f.)].—Subsidiary vertical aerofoils set parallel to the normal direction of motion of an aircraft.*

Flaps, Balancing or Wing [*ailerons* (m.)].—An inaccurate term; should be "Ailerons." Aerofoils used for causing an aeroplane to roll about its longitudinal axis for the purpose of balancing.*

Flight Speed [*vitesse par rapport à l'air*].—The speed through the air, as distinct from speed over the land.

Flight Path [*ligne* (f.) *de vol* (m.)].—The path of the centre of gravity of an aircraft with reference to the air.

Floats [*flotteurs* (m.) *d'hydravions*].—Water-tight compartments of suitable shape carried by seaplanes.

Flying Boat [*hydravion monocoque* (m.)].—A hydro-aeroplane or machine of which the main boat-like body is also a support on the water.

Flying or Lift Wires [*haubans inférieurs* (m.) *de soutien*].—The wires employed to transfer the lift of the planes to the fuselage or other part of an aeroplane.

Flying Position.—See "Attitude."

Force, Cross-Wind [*force contre-vent*].—The component of the resultant force which acts along the cross-wind axis.

Force, Lateral [*force latérale*].—The component of the resultant force which acts along the lateral axis.

Force, Longitudinal [*force (f.) longitudinale*].—The component of the resultant force which acts along the longitudinal axis.

Force, Normal [*force (f.) normale*].—The component of the resultant force which acts along the normal axis.

Frame [*fuselage* (f.)].—A colloquial term; should be "Fuselage" (see below).

Fuselage [*fuselage* (f.)].—Of an aeroplane—that part which usually contains the engine, crew, tanks, etc., and to which the planes, undercarriage, and other organs are attached.* Sometimes called the body or frame.

Fuselage Fairing [*carénage* (m.) *du fuselage*].—The stream lining or covering on top of the rear portion of the fuselage. Sometimes called the fuselage cowling.

Fusiform [*fusiforme, fuselé*].—Stream-lined.

Gaining Pitch [*pas* (m.) *gagnant*].—A propeller is said to have a gaining pitch when the angle of the blade to the axis at any section increases from front to back; intended to deflect the air without shock, on the same principle as the camber of an aerofoil.

Gap [*écartement des plans*].—The distance between the upper and lower wings of a biplane. For specific purposes the points between which it is measured should be indicated.* It should preferably be measured perpendicular to the chord.

Gauchissement [*gauchissement* (m.)].—Warping the ends of the principal planes in order to preserve lateral equilibrium, in this way doing without balancing planes or ailerons.

Girder [*poutre* (f.)].—A structural member intended to resist bending, and built up so as to combine strength and lightness.

Glide [*planer*].—To descend in an ordinary flying attitude when the engine is giving no thrust.

Glider [*planeur*].—A gliding or soaring appliance which is not self-propelling.

• **Gliding** [*vol plané*].—To descend on an aeroplane (or on a glider) without the aid of the engine.

Gliding Angle [*angle plané*].—The angle between the horizontal and the path along which an aeroplane, in ordinary flying attitude, but not under engine power, descends in still air.*

Ground Lag [*traînée au sol*].—The distance, measured on the ground, between the spot where a body falls and the spot where it would have fallen had the air offered no resistance to its motion.

Guy Wires [*haubans* (f.)].—The stays, or ties used in conjunction with a strut.

Gyroplane [*gyroplan*].—A flying machine with revolving wings. A combination of a helicopter and an aeroplane.

Gyroscope [*gyroscope* (m.)].—A heavy circular wheel rotating at high speed. This tends to maintain the direction of its axis of rotation in spite of disturbing forces.

Hangar [*hangar* (m.)].—A shed for housing aeroplanes or balloons.

Head Resistance [*résistance* (f.) à l'avancement].—The resistance offered by the air to the passage of a body. Due partly to skin friction and partly to eddy formation. Drag.

Helicopter [*hélicoptère* (m.)].—A flying machine whose lift is obtained by airscrews on approximately vertical shafts. A vertical airscrew.

Helix [*hélice* (f.)].—The trace of a point moving uniformly round a cylinder, at the same time ascending at a uniform rate.

Ichthyoid [*ichthyoïde* (adj.)].—Fish-shaped. A body having a practical streamline form in viscous fluids.

Incidence, Angle of, or Angle of Attack [*angle* (m.) *d'incidence* (m.) *ou angle* (m.) *d'attaque* (m.)].—The angle a plane makes with the direction of its motion relative to the air. The angle is usually measured between the chord of the plane and the direction of motion.

Incidence (Rigging) [*angle d'incidence* (m.) *haubanage d'incidence*].—The angle between the chord of a main plane and the horizontal when the aeroplane is in the rigging position. See 227, and distinguish from 171.

• **Inclinometer** [*clinomètre* (m.)].—An instrument for measuring the angle of slope of an aircraft, referred to the horizontal.*

Indraught [*filet d'air* (m.)].—The air stream resulting from the approach of air to an airscrew during rotation.*

Inherent or Natural Stability [*stabilité automatique* (f.)].—That property of an aeroplane by which it tends to return to its normal attitude of flight without the application of the controls.

- Instability** [*instabilité* (f.)].—The quality by virtue of which any disturbance of steady motion tends to increase.
- Instability Spin** [*vrille d'instabilité* (f.)].—The tendency of an aeroplane to rotate rapidly about its normal axis. Usually associated with stalling. A special case of lateral divergence.
- Instability Spiral** [*spirale* (f.) *d'instabilité*].—The tendency of an aeroplane to depart from straight flight by a combination of side-slipping and banking, the latter being always too great for the turn. A special case of lateral divergence.
- Interplane Strut** [*mat* (m.) *de cellule* (f.)].—The vertical or slightly inclined struts generally in pairs front and rear in biplanes and multiplanes, connecting the spars of a lower wing to the corresponding spars of the wing above as distinct from the centre section strut (q.v.).
- I.S. or I.S.M.**—International Standard Metric System screw threads for bolts.
- Isobars** [*lignes* (f.) *isobares* (f.)].—Lines on a pressure map where the heights of the barometric readings are the same.
- Joystick** [*manche* (m.) *à balar*].—A colloquial term for control column (q.v.).
- Kathedral Angle** [*angle cathédrale* (f.)].—The name of the angle when the wings of an aeroplane are bent downwards or in a negative direction.
- Keel** [*quille dérive* (f.)].—A vertical plane arranged longitudinally under a flying machine.
- King Post** [*guignol* (m.)].—A strut placed normal to a spar and used in combination with ties to reduce the bending moment.
- Landing Gear** [*train* (m.) *d'atterrissage* (m.) *châssis* (m.)].—A colloquial term; see "Undercarriage."
- Landing Wires** [*haubans* (m.) *supérieurs d'atterrissage* (m.)].—Anti-lift wires used to take the weight of the wings when the machine is resting on the ground and to take up stresses.
- Lateral Axis** [*axe* (m.) *latérale*].—A straight line through the centre of gravity normal to the plane of symmetry of aircraft. In an aeroplane the lateral axis is conveniently taken parallel to a line joining the wing tips, and when looking in the direction of motion of the aircraft the positive branch of the axis is to the left. In mathematical theory this axis is taken as the "y" axis.
- Lateral Divergence** [*divergence latérale*].—The instability which leads to spin or to a spiral with increasing rate of turn. More generally any non-periodic combination of rolling (*roulis*), yawing (*marcher en crabe*), and side-slipping (*glissade sur l'aile*).

Lateral Force [*force latérale*].—The component along the lateral axis of the resultant force on an aircraft. This includes the resolved component of gravity. Where the gravity component is neglected the term lateral air force should be preferred.

Lateral Oscillation [*oscillation latérale*].—Any motion which is made up of a periodic variation of the rolling, yawing, and side-slipping of an aircraft.

Lateral Stability [*stabilité latérale*] (where separable from the longitudinal stability).—The stability of the motions out of the plane of symmetry, i.e., of side-slipping, rolling, and yawing.

Lateral Velocity, or Rate of Side-Slipping [*vitesse latérale ou vitesse de glissement sur l'aile*].—The component velocity of an aircraft along its lateral axis.

Leading Edge [*bord (m.) d'attaque (m.)*].—Of a plane or aerofoil—the forward edge. Normally this is thicker than the trailing edge.

Leeward [*sous le vent*].—Away from the wind.*

Leeway [*dérive (f.)*].—Lateral drift to leeward. Motion purely relative to a fixed point.

Left and Right of an Aeroplane [*babord et tribord*].—The pilot's left and right respectively when facing the direction of flight, looking from the tail. Corresponds to port and starboard of a ship. Port and starboard are preferable terms.

Left-Hand Engine [*moteur (m.) à gauche*].—An engine designed to drive a left-hand airscrew and of which the airscrew shaft rotates left-handed.

Length [*longueur (m.)*].—When used of an aeroplane—the fore-and-aft dimension.

Lift [*poussée (f.)*].—The component of the force due to the relative wind along the lift axis. The force perpendicular to the flight-path in the plane of symmetry.

Lift Axis [*axe de sustentation*].—A straight line in an aircraft which passes through the centre of gravity, is in the plane of symmetry and is perpendicular to the direction of the relative wind.

Lift or Flying Wires [*haubans (m.) inférieurs*].—The wires employed to transfer the lift of the wings to the fuselage or other part of an aeroplane.

Lifting Tail [*empennage (m.) portant*].—A tail in which the horizontal plane is set to carry a proportion of the weight of the aeroplane.

Line Error [*ligne (f.) d'erreur*].—The perpendicular distance from the line of attack, of point of impact of a body.

Loading [*capacité (f.) de charge (f.)*].—In the case of surface, the weight carried per unit area of supporting surface. Usually expressed in pounds per square foot, or kilogrammes per square metre. In the case of power, it is the weight carried per unit of power. Usually expressed in pounds per horse-power.

Loading.—The weight per unit area carried by an aerofoil.

Longeron [*longeron (m.)*].—See "Longitudinal."

Longitudinal Axis [*axe (m.) longitudinale*].—A line in the plane of symmetry of an aircraft through the centre of gravity, fore and aft. In general theoretical discussions of the motion of an aeroplane this may be taken as parallel to the airscrew axis. The positive direction to be taken backwards from the centre of gravity. In mathematical theory this axis is taken as the "x" axis.

Longitudinal Force [*force (f.) longitudinale*].—The component along the longitudinal axis of the resultant force on an aircraft. This includes the resolved component of gravity. Where the gravity component is neglected the term longitudinal air force should be preferred.

Longitudinal Divergence [*divergence longitudinale*].—The instability which leads to a nose-dive or to stalling. More generally, any non-periodic increasing disturbance which continues.

Longitudinal Oscillation [*oscillation (f.) longitudinale*].—Any motion which is made up of a periodic variation of the flight speed, the rise and fall, and the pitching of an aircraft. The longitudinal motion may contain one oscillation of relatively long period, sometimes called phugoid, and one of relatively short period.

Longitudinals [*longerons (m.)*].—Of an aeroplane, the long fore-and-aft spars connecting the main with the subsidiary supporting or controlling surfaces.

Longitudinal Stability [*stabilité (f.) longitudinale*] (where it is separable from the lateral stability).—The stability of the motions in the plane of symmetry, *i.e.*, of the rise and fall, forward motion, and pitching.

Longitudinal Velocity [*vitesse (f.) longitudinale*].—The component velocity of an aircraft along its longitudinal axis. Symbol U.

Lug, Wiring [*patte (f.) oreille*].—Any plate pierced to form a wire connection.

Magneto [*magnéto (m.)*].—A dynamo with permanent steel magnets used for firing the mixture in a petrol engine cylinder.

Maximum Horse-Power of an Engine [*puissance (f.) maximum d'un moteur*].—The maximum horse-power that may be maintained for short periods (say 5 minutes).

Maximum Revolutions [*révolutions (f.) maxima*].—The maximum number of revolutions per minute that may be maintained for short periods (say 5 minutes).

Monoplane [*monoplan (m.)*].—A heavier-than-air flying machine in which the main supporting surface consists of a single plane, or pair of wings.

Multicellular [*multicellulaire*].—A flying apparatus with many planes of cellular construction.

Multiplane [*multiplan (m.)*].—A flying machine having more than two parallel planes or supporting surfaces.

Nacelle [*nacelle (f.)*].—The car of a balloon or dirigible. An auxiliary enclosed shelter for passengers on an aeroplane or for an engine. An additional body distinct from the fuselage.

Natural or Inherent Stability [*stabilité automatique*].—That property of an aeroplane by which it tends to return to its normal attitude of flight without the application of the controls.

Non-Lifting Tail [*empennage (m.) non-portant*].—A tail in which the horizontal plane is set so that it carries none of the weight of the machine.

Non-Rigid [*demi-rigide*].—A term applied to a dirigible balloon whose envelope is not built on a stiff framework.

Normal [*normal*].—Perpendicular to the direction of flight or of an air current.

Normal Axis [*axe (m.) normal*].—A straight line in the plane of symmetry at right angles to the longitudinal axis through the centre of gravity. Where the longitudinal and lateral axes are horizontal, the normal axis is vertical. The positive direction is upwards in all aircraft. In mathematical theory this axis is taken as the "z" axis.

Normal Force [*force (f.) normale*].—The component along the normal axis of the resultant force on an aircraft. This includes the resolved component of gravity. Where the gravity component is neglected the term normal air force should be preferred.

Normal Horse-Power of an Engine [*puissance (f.) HP. normale d'un moteur*].—The highest horse-power which can be safely maintained for long periods (B.H.P.).

Normal Revolutions [*révolutions (f.) normales*].—The highest number of revolutions per minute that may be maintained for long periods.

Normal Velocity [*vitesse (f.) normale*].—The component velocity of an aircraft along its normal axis. Symbol W.

Nose Dip [*piquer*].—A steep descent (colloquial). See "Dive."

Nose Rib [*neuvure*].—*Cf.* former rib.

Ornithopter [*ornithoptère* (m.), *machine* (f.), à ailes battantes].—A flapping wing flying machine intended to imitate a bird.

Orthopter [*orthoptère* (f.)].—A flapping wing flying machine.

Oscillation, Lateral [*oscillation* (f.) *latérale*].—Any motion which is made up of a periodic variation of the rolling, yawing, and side-slipping of the aircraft. In an aeroplane, the bank and direction of turn are opposed during the oscillation.

Oscillation, Longitudinal [*oscillation* (f.) *longitudinale*].—Any motion which is made up of a periodic variation of the flight speed, the rise and fall, and the pitching of aircraft. The *phugoid oscillation* is a special case of *longitudinal oscillation*.

Oscillation, Phugoid [*oscillation phugoïde*].—A slow motion characteristic of the disturbed longitudinal motion of an aeroplane. A special case of longitudinal oscillation.

Oscillation, Stable [*oscillation* (f.) *stable*].—An oscillation which tends to die out.

Oscillation, Unstable [*oscillation* (f.) *instable*].—An oscillation which increases its amplitude in successive periods.

Outrigger [*poutre de réunion*].—The framework connecting the main planes with the tail-piece or the prow. "Tail-boom" is a preferred term.

Overhang [*extension d'aile supérieure, saillie* (f.) *surplomb* (m.) *débordeant*].—The portion of a plane beyond the outermost inter-plane strut.

Pancake, To [*plaquer*].—To descend steeply, with the wings at a very large angle of incidence like a parachute. Contrast "Dive."* To permit a machine to lose its flying speed and fall.

Performance [*performance* (f.)].—The term for the speed rate of climb and ceiling reached by an aeroplane under given conditions of load.

Period [*période* (f.)].—The time taken for a complete oscillation.

Phugoid Oscillation [*oscillation phugoïde*].—A long period oscillation characteristic of the disturbed longitudinal motion of an aeroplane. Cf. "Longitudinal Oscillation."

Pitch, To [*tanguer*].—To plunge in the fore-and-aft direction (nose up or nose down). Contrast this with "Roll."* Rotation about the lateral axis.

Pitching [*tangage* (m.)].—Angular motion about the lateral axis.

Pitching Moment [*moment de tangage*].—The component about the lateral axis of the couple due to the relative wind.

Pitch of a Screw [*pas (m.) d'hélice*].—The distance that would be travelled by a screw in one revolution if there was no slip. The distance from the centre of one thread on a screwed shaft to the centre of the next adjacent thread.

Pitot Tube [*tube de pitot (m.)*].—A tube with open end facing the wind, which, combined with a static pressure or suction tube, is used in conjunction with a gauge to measure fluid pressure or velocities.*

Plane [*plan (f.) d'aéro*].—The term applied to the principal aerofoils of a flying machine. In this respect it is not quite accurate, as these surfaces are never flat, but cambered.

Plane of Symmetry [*plan symétrique*].—An imaginary plane dividing an aircraft longitudinally into two exactly similar parts, right and left hand. This is the plane containing the normal and longitudinal axes.

Port [*babord (m.)*].—The left-hand side when facing the normal direction of motion.

Pressure Head [*tuyau de pression (f.)*].—A combination of Pitot tube and static pressure or suction tube, which, in conjunction with a gauge, is used to measure fluid pressures or velocities.*

Pressure Tube, Static [*tuyau de pression statique*].—A tube (usually with holes in its side past which the fluid flows) so designed that the pressure inside it equals the pressure exerted by the fluid on any body at rest in the fluid. Used as part of a pressure head.*

Propeller [*hélice (f.)*].—An airscrew behind the main supporting surfaces. Compare "Tractor Screw."*

Propeller or Airscrew Torque [*couple (m.) d'une hélice*].—The reaction of an airscrew which tends to cause an aeroplane to turn about its longitudinal axis in a direction opposite to that in which the screw is revolving.

Prow [*proue (f.)*].—A vertical plane fixed in the front of a flying machine to improve the control of the vertical rudder.

Pterygoid Aspect [*allongement ptérygoïde*].—Wing-like aspect. The converse of apteroid aspect, *i.e.*, with the lesser dimension in the direction of flight, as in the wing plan-form of a bird. Broad-side aspect.

Pusher [*atéroplan à hélice propulsive*].—An aeroplane or seaplane on which the planes are in front of the airscrew.

Pusher Engine.—An engine which has the airscrew mounted at the rear end when in position in an aircraft.

Pylon [*pylône (m.)*].—A mast or post.*

Radiator [*radiateur (m.)*].—A vessel having a large cooling surface for cooling the jacket water of a petrol engine.

R.A.E.—Royal Aircraft Establishment, formerly the Royal Aircraft Factory, and previously the Balloon Factory, Royal Engineers.

Rate of Climb [*vitesse de montée*].—The vertical component of the velocity of an aircraft relative to the air. This must be distinguished from the rate of rising from the ground which may be affected by vertical currents.

Remou [*remous* (m.)].—A local eddy in the air, causing a momentary change in the lift.

Resistance Derivatives [*dérivés de résistance* (f.)].—Quantities expressing the variation of the forces and moments on aircraft due to disturbance of steady motion. They represent the experimental basis of the theory of stability, and from them the periods and damping factors of aircraft can be calculated.

Restoring Moment [*moment* (m.) *de redressement*].—A moment which tends to restore an aircraft after any rotational disturbance to its previous attitude.

R.F.C.—Royal Flying Corps, now the Royal Air Force.

Rib [*nerveure* (f.) *membrure* (f.)].—Of a wing, a light fore-and-aft member which carries the fabric for the purpose of giving the desired cross section to the wing.*

Rib, Compression [*nerveure* (f.) *de compression* (f.)].—A rib designed to act as a strut between front and rear spars of a wing.*

Riblet [*nerveure* (f.) *du nez*].—Nose rib.

Rigging Position of an Aeroplane [*position* (f.) *de réglage* (m.)].—Position in which an arbitrary datum line fixed in regard to the aeroplane is horizontal.

Right and Left of an Aeroplane [*tribord et babord*].—The pilot's right and left respectively when facing the direction of flight, looking from the tail. Corresponds to starboard and port of a ship. Starboard and port are preferable terms.

Right-Hand Engine [*moteur* (m.) *à droite*].—An engine designed to drive a right-hand airscrew, and of which the airscrew shaft rotates right-handed.

Righting Tips [*stabilisateurs* (m. pl.)].—Balancers attached to the lateral extremities of the main plane of an aeroplane.

Rigid [*rigide*].—A term applied to a dirigible balloon whose envelope is provided with a stiff framework to keep it in shape.

R.N.A.S.—Royal Naval Air Service.

Roll, To [*rouler, vol* (m.) *en tonneau*].—To turn about the fore-and-aft axis.* Rotation about the longitudinal axis.

Rolling [*roulis* (m.)].—Angular motion about the longitudinal axis.

- Rolling Moment** [*moment (m.) de rouler*].—The component about the longitudinal axis of the couple due to the relative wind.
- Rotary Derivatives** [*dérivés rotatifs*].—Resistance derivatives due to rotation of the aeroplane.
- Rudder** [*gouvernail (m.)*].—A subsidiary aerofoil (in an aeroplane more or less perpendicular to the main supporting surfaces) by means of which an aircraft is turned to right or left.*
- Rudder Bar** [*palonnier de direction (m.)*].—The foot-bar, by means of which the rudder of an aeroplane is worked.*
- Rudder Post** [*étambot (m.)*].—The main post of a rudder.* Sometimes called the stern post.
- Scarfig** [*assemblage (m.)*].—A method of repairing a broken spar by adding a new piece, the joints of which, on to the broken part, are very long compared with the cross section.
- Screw, Air** [*hélice (f.)*].—An aerofoil so shaped that its rotation about an axis produces a force along that axis for driving an aircraft.*
- Seaplane** [*hydro-aéroplane (m.)*].—An aeroplane provided with floats for alighting on water.
- Semi-rigid** [*demi-rigide*].—A term applied to a dirigible balloon which maintains its shape partly by the assistance of a suitable framework.
- Serve** [*setier de ficelle (f.) ou de fil de fer (m.)*].—To bind closely with twine or wire.
- Side Drift** [*dérive*].—The distance drifted. The speed of drifting. The word "drift" having a well-accepted nautical significance should be avoided as far as possible in the sense of "head resistance" or "drag."*
- Side Slip, To** [*glissade sur l'aile*].—In an aircraft, to move more or less broadside on relatively to the air.* Side slip is caused by inadequate banking.
- Side Slipping, Rate of** [*vitesse (f.) de glissade sur l'aile*].—The velocity of an aircraft along the lateral axis.
- Skid** [*patin (m.)*].—A part of the alighting gear of an aircraft arranged to slide along the ground.*
- Slip of a Screw** [*retard*].—The ratio between the effective distance travelled by a screw propeller or tractor in one revolution and the distance represented by the pitch of that screw.
- Slipstream** [*zone (f.) balayée par l'hélice*].—The air stream resulting from the changed motion of the air which has passed through an airscrew during its rotation.

Soaring [*planer*].—Gliding in a rising current of air.

Span, of Aeroplanes [*envergure* (f.)].—The maximum transverse dimension.* The distance from plane tip to plane tip.*

Spar [*longeron* (m.)].—A long piece of timber or other material. In a plane, either of the beams which run transversely to the aircraft, and transfer the lift from the ribs to the frame and bracing.*

Spin [*vrille* (f.)].—A continued rotation about any axis.

Spin and Spin Instability [*vrille* (f.) et *tendance à faire vrille* (f.)].—The tendency of an aeroplane to rotate rapidly about its normal axis. Usually associated with stalling. A special case of *Lateral Divergence*.

Spinning [*vrille* (f.)].—The rapid rotation of an aeroplane during descent, approximately about the direction of motion.

Spinning Dive [*descente* (f.) en *vrille*, *vrille* (f.)].—A diving descent combined with a continued rotation about the direction of motion of the centre of gravity of an aeroplane.

Spiral Instability [*instabilité spirale*].—The instability on account of which an aeroplane tends to depart from straight flight by a combination of side-slipping and banking, the latter being always too great for the turn. A special case of *Lateral Divergence*.

Splice [*spissure*].—To unite two pieces of rope by interlacing the strands. To connect pieces of wood or metal by means of overlapping parts and securing the same by bolts or other fastenings, such as by serving with wire or twine.

Spread [*envergure* (f.)].—The span or transverse dimension of an aeroplane.

Stable Oscillation [*oscillation* (f.) *stable décroissante*].—An oscillation which tends to die out.

Stabiliser [*stabilisateur* (m.)].—Any surface, such as a fin or horizontal plane, designed to give inherent stability to an aeroplane. Sometimes incorrectly used instead of “*aileron*.”

Stability [*stabilité* (f.)].—The quality by virtue of which any disturbance of steady motion tends to decrease.

Stability, Biquadratics for [*biquadratiques* (f.) de *stabilité* (f.)].—The equations from which the longitudinal stability and lateral stability of aeroplanes and airships are finally calculated. They are deduced from the theory of stability and a knowledge of the resistance derivative.

Stability, Natural or Inherent [*stabilité* (f.) *automatique*].—That property of an aeroplane by which it tends to return to its normal attitude of flight without the application of the controls. The tendency to eliminate disturbances of the steady motion.

Stagger [*décalage* (m.)].—Of planes. When the planes of a biplane are set with the upper one slightly ahead of, or abaft of the other, they are said to be staggered. The stagger is measured by the angle made by the line joining the leading edges with the normal to the chord of the aeroplane. It is convenient to call the stagger positive if the upper plane is ahead of the lower.*

Stalling [*cabrer par manque de vitesse*].—The condition of an aeroplane caused by either (1) climbing too steeply; or (2) insufficient engine power at low speed; (3) gliding too slowly, which produces a loss in height, speed, and controllability.

Starboard [*tribord*].—The right-hand side when facing the normal direction of motion.

Static Pressure Tube [*tuyan* (m.) *de pression statique*].—See under "Pressure."

Statoscope [*statoscope* (m.)].—An instrument to detect the existence of a small rate of ascent or descent.*

Stays [*haubans* (m.)].—Guy wires or ties used in conjunction with a strut.

Stern Post [*étambot* (m.)].—Same as rudder post (*q.v.*).

Strainer [*tendeur* (m.)].—An appliance bearing a suitable mesh for straining impurities from petrol and other fluids. Also compare "turnbuckle."*

Streamline [*filet* (m.) *d'air*].—The path of a small portion of a fluid, supposed continuous, moving relatively to a solid body. The term is commonly used only of such paths as are not eddying, but the distinction should be made clear by the context.* As an adjective—applied to members designed specially with a view to giving low head resistance, *e.g.*, streamline struts, streamline wires.

Streamline Form [*forme* (f.) *fuselée*].—That shape of a body which offers the least resistance to its passage through the air or other fluid. A shape that is fish-like in section. Ichthyoid.

Strut [*mât* (m.) *montant*].—A structural member intended to resist compression in the direction of its length.*

Subsidence [*subsidence* (f.)].—A dead beat motion in which the disturbance dies out without showing an oscillation.

Supercharger Engine [*dispositif* (m.) *de sur-alimentation* (f.)].—This term is used when the cylinders are charged with a greater weight of charge than would be induced normally at atmospheric pressure.

Swage [*estampe*].—To beat down, to reduce in thickness. Swaged wires are those with the portion between the threaded ends flattened out, so as to obtain a more stream-like effect.

Sweep [*en flèche*].—The vertical distance within which the air is given a downward velocity by the horizontal passage of an aerofoil.

Sweepback [*en flèche (ailes)*].—The angular set back of the wings relatively to the main body.

Sswerve [*s'écarter, se détourner*].—The movement of an aeroplane about an approximately vertical axis; a loss of stability about a similar axis.

Tail Booms [*poutres (f.) de réunion*].—The longitudinals or framework by which the tail of a pusher is connected to the main planes. Sometimes called outriggers.

Tail, Lifting [*empennage (m.) porteur*].—A tail which is so arranged as to carry a proportion of the weight of an aeroplane.

Tail, Non-Lifting [*empennage (m.), non porteur*].—A tail which is not designed to sustain any of the weight of an aeroplane.

Tail Plane [*plan (m.) fixe, stabilisateur (m.)*].—A horizontal aerofoil attached to the tail of an aeroplane which affects the longitudinal stability of the machine.

Tail Slide [*glissement (m.) sur la queue*].—The rearward motion which an aeroplane may be made to take after having been brought into a stalling position.

Tail Unit [*empennage (m.)*].—The after part of an aircraft, usually carrying certain controlling organs.

Tandem [*tandem*].—One before the other.

Tenuity Factor [*correction (f.) due à la diminution de la pression atmosphérique*].—A correction employed in bomb-dropping calculations to allow for the decrease of atmospheric density with altitude.

Thimble [*cosse (f.)*].—A metal ring, grooved to receive a rope and thus form a terminal for the rope.

Tie [*attache (f.)*].—A structural member intended to resist tension.*

Tilt [*bascule (f.)*].—An elevation or depression of the front of an aeroplane or aerofoil to obtain a change of altitude.

Top Surface Camber [*courbure extradors*] (of a plane section).—The convexity of a plane section. The camber is usually measured (as a fraction of the chord) by the maximum height above the chord.*

Top Load Wires [*haubans supérieurs (m.)*].—Wires intended mainly to resist forces in the opposite direction to the lift.*

Top Warp Wires [*câble (m.) de gauchissement*].—Top load wires connected to the back spar and passing from plane to plane to allow the planes to warp.*

Torque of an Aircscrew [*couple (m.) d'une hélice (f.)*].—The reaction of an aircscrew which tends to cause an aeroplane to turn about its longitudinal axis in a direction opposite to that in which the screw is revolving.

- Tractor Engine** [*moteur* (m.) à *hélice* (f.) *tractive*].—An engine which has the airscrew mounted in front when in position in an aircraft.
- Tractor Machine** [*aéroplane* (m.) à *hélice* (f.) *tractive*].—An aeroplane with airscrew mounted in front of the main supporting surfaces.*
- Tractor Screw** [*hélice tractive*].—An airscrew mounted in front of the main supporting surfaces.*
- Trail** [*retard* (f.)].—The horizontal distance which a bomb trails behind a vertical dropped from a uniformly moving aircraft.
- Trail Angle** [*angle* (m.) *de traînée*].—The small angle by which the bomb, as viewed from a uniformly moving aircraft, appears to trail behind the vertical.
- Trailing Edge** [*bord de sortie*].—The rear edge.* Normally this is much thinner than the leading edge.
- Triplane** [*triplan*].—A flying machine with three planes superimposed.
- Turnbuckle** [*tendeur* (m.)].—A wire tightener.*
- Undercarriage** [*châssis* (m.) *d'atterrissage* *train* (m.) *d'atterrissage*].—That part of the aircraft beneath the body intended for its support on land or water and to absorb the shock of alighting.* Sometimes called the chassis, landing gear, or alighting gear.
- Under Surface Camber** [*courbure intrados*] (of a plane section).—The convexity of a plane section. The camber is usually measured (as a fraction of the chord) by the maximum height above the chord.*
- Unstable Oscillation** [*oscillation* (f.) *instable*].—An oscillation of which the amplitude tends to increase.
- Veer, of the Wind** [*saut de vent* (f.) “*le vent a changé cap pour cap*,” *wind has veered right round*].—To change direction sunwise (clockwise).*
- Velocity, Lateral** [*vitesse* (f.) *latérale*].—The velocity of an aircraft along the lateral axis.
- Velocity, Longitudinal** [*vitesse* (f.) *longitudinale*].—The velocity of an aircraft along the longitudinal axis.
- Velocity, Normal** [*vitesse* (f.) *normale*].—The velocity of an aircraft along the normal axis.
- Velocity of Side Slip** [*vitesse* (f.) *de glissade*].—The speed with which the craft moves broadside on with respect to the air. Distinguish from “drift” (*q.v.*).*
- Velometer** [*indicateur de vitesse* (m.)].—An air-speed indicator.
- Vol Pique or Dive** [*vol* (m.) *piqué*].—A steep glide or descent.
- Volplane** [*descente en vol plané* (m.)].—Descent on an aeroplane (or on a glider) without the aid of the engine.

Wires, Landing Drag [*câble (m.) antérieur*].—The internal bracing wires of a plane, connected from the front spar to the rear spar diagonally inwards in each cellule, *i.e.*, opposite to the flying drag wires.

Wires, Lift, or Flying [*haubans (m.) de soutien intérieur*].—Wires, the principal function of which is to transfer the lift of the planes to the body or other part of the aeroplane structure.*

Wires, Warp [*câble (m.) de gauchissement*].—Lift wires connected to the back spar and controlled so as to move its outer end down for the purpose of warping the wing.*

Wires, Top Load [*haubans intérieurs*].—Wires intended mainly to resist forces in the opposite direction to the lift.* Also referred to as anti-flying, anti-lift, or weight wires.

Wires, Top Warp [*câble (m.) de gauchissement*].—Top load wires connected to the back spar and passing from plane to plane to allow the planes to warp.*

Yaw, To [*instabilité de direction*].—An aircraft is said to yaw when its fore-and-aft axis turns to right or left out of the line of flight. The angle of yaw is the angle between the fore-and-aft axis of the aircraft and the instantaneous line of flight.* Rotation about the normal axis.

Yawing [*embardement*].—Angular motion about the normal axis.

Yawing Moment [*moment d'embardement*].—The component about the normal axis of the couple due to the relative wind.

* Official definitions of the Aeronautical Society of Great Britain (1914).

D.E.D.A. (Detachable Data) System
R. Borlase Matthews' Patents (provisionally protected) U.S. Patents applied for.

Wires, Anti-Drag [*câble (m.) opposé au câble de trainée*].—Wires strained in the opposite direction to the drag wires to keep the latter taut. Also to assist in keeping the plane in its proper attitude relative to the fuselage.

Wires, Bulkhead [*câble (m.) de cloison (f.)*].—Wires by which the fuselage is braced on planes at right angles to its length.*

Wires, Drag [*câble (m.) de trainée câble (m.) de recul*].—Wires, the principal function of which is to transfer the drag of the wings to the body or other part of the aeroplane structure. Wires intended mainly to resist forces in the opposite direction to the drag are sometimes called "anti-drag wires."

Wires, Flying [*câble (m.) de levée*].—A vague term for wires for bearing the main load of a machine in the air.

Wires, Flying Drag [*haubans (m.) de résistance passive*].—The internal bracing wires of a plane, connected from the front spar to the rear spar diagonally outwards in each cellule, *i.e.*, opposite to the landing wires in the same cellule.

Wires, Incidence [*câble (m.) d'incidence*].—Wires on the planes coplaner with the interplane struts passing from front truss to rear truss.

Wires, Landing or Anti-Lift [*câble (m.) opposé au câble de levée*].—The wires used to resist forces in the opposite direction to the lift. Also employed to take the weight of the planes when the aeroplane is resting on the ground and to take landing stresses.

Wires, Anti-Drag [*haubans de résistance passive d'atterrissage*].—The internal bracing wires of a plane connected from the front spar to the rear spar diagonally inwards in each cellule, *i.e.*, opposite to the flying drag wires.

Wires, Drag [*câble (m.) de trainée, câble (m.) de recul*].—Wires, the principal function of which is to transfer the drag of the planes to the body or other part of the aeroplane structure. Wires intended mainly to resist forces in the opposite direction to the drag are sometimes called "anti-drag wires."*

Wire-Strainer [*tendeur (m.)*].—A wire tightener.*

Wire, Streamline [*câble (m.) fuselé*].—Wire of oval or egg shape section. A R.A.F or raf wire.

Wires, Warp [*câble (m.) de gauchissement intérieur*].—Lift wires connected to the back spar and controlled so as to move its outer end down for the purpose of warping the wing.

W. S.—Whitworth standard screw threads for bolts.

Woof or Weft [*trame (f.)*].—The yarn running across the cloth, which is woven into the warp by the shuttle.

Wires, Landing Drag [*câble (m.) antérieur*].—The internal bracing wires of a plane, connected from the front spar to the rear spar diagonally inwards in each cellule, *i.e.*, opposite to the flying drag wires.

Wires, Lift, or Flying [*haubans (m.) de soutien intérieur*].—Wires, the principal function of which is to transfer the lift of the planes to the body or other part of the aeroplane structure.*

Wires, Warp [*câble (m.) de gauchissement*].—Lift wires connected to the back spar and controlled so as to move its outer end down for the purpose of warping the wing.*

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Yaw, To [*instabilité de direction*].—An aircraft is said to yaw when its fore-and-aft axis turns to right or left out of the line of flight. The angle of yaw is the angle between the fore-and-aft axis of the aircraft and the instantaneous line of flight.* Rotation about the normal axis.

Yawing [*embardement*].—Angular motion about the normal axis.

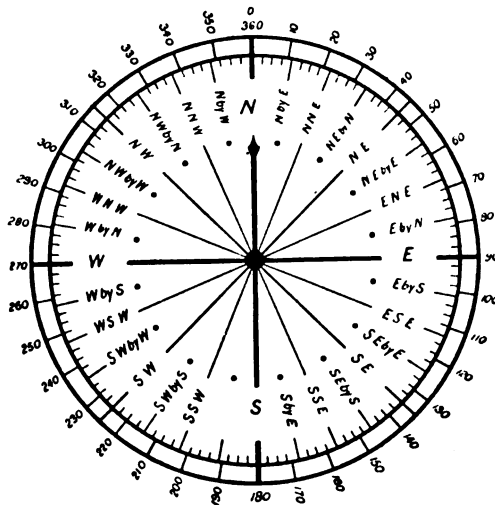
Yawing Moment [*moment d'embardement*].—The component about the normal axis of the couple due to the relative wind.

* Official definitions of the Aeronautical Society of Great Britain (1914).

D.E.D.A. (Detachable Data) System
R. Borlase Matthews' Patents (provisionally protected) U.S. Patents applied for.

To Steer a Course by Compass.—A mark is made on the case of the compass exactly opposite the N. point on the card when the aeroplane is lying magnetic N. and S. This mark is known as the "lubber line," or "lubber point." To follow a given course, say N.W. by N., $\frac{1}{4}$ N., the aeroplane is turned until the corresponding point on the card is opposite the lubber line; the two marks must then be kept in line until a different course is required. The "given course" is obtained by (a) adding to the angle obtained from the map (the "map course") the local variation, this gives the "magnetic course"; (b) correcting this result for the deviation noted on the adjustment card, this gives the "compass course." Luminous paint and also electric lamps are used to facilitate steering at night.

An allowance for leeway due to side winds must be made; experience with the same aircraft in different winds will enable the pilot to judge the leeway he is making with a considerable degree of accuracy, by noting the apparent direction of travel of the ground. Instruments designed to estimate the leeway by observation of this direction are known as drift or navigation sights, bearing plates, bomb sights, etc.



Points of the Compass.

629.13.0042

POINTS OF THE COMPASS

Points.		Angle with Meridian.		
		Degs.	Min.	Secs.
N.	N.	0	0	0
N., $\frac{1}{2}$ E.	N., $\frac{1}{2}$ W.	2	48	45
N., $\frac{1}{2}$ E.	N., $\frac{1}{2}$ W.	5	37	30
N. by E., $\frac{1}{4}$ N.	N. by W., $\frac{1}{4}$ N.	8	26	15
N. by E.	N. by W.	11	15	0
N. by E., $\frac{1}{4}$ E.	N. by W., $\frac{1}{4}$ W.	14	3	45
N.N.E., $\frac{1}{2}$ N.	N.N.W., $\frac{1}{2}$ N.	16	52	30
N.N.E., $\frac{1}{4}$ N.	N.N.W., $\frac{1}{4}$ N.	19	41	15
N.N.E.	N.N.W.	22	30	0
N.N.E., $\frac{1}{4}$ E.	N.N.W., $\frac{1}{4}$ W.	25	18	45
N.N.E., $\frac{1}{2}$ E.	N.N.W., $\frac{1}{2}$ W.	28	7	30
N.E. by N., $\frac{1}{4}$ N.	N.W. by N., $\frac{1}{4}$ N.	30	56	15
N.E. by N.	N.W. by N.	33	45	0
N.E. by N., $\frac{1}{4}$ E.	N.W. by N., $\frac{1}{4}$ W.	36	33	45
N.E., $\frac{1}{2}$ N.	N.W., $\frac{1}{2}$ N.	39	22	30
N.E., $\frac{1}{4}$ N.	N.W., $\frac{1}{4}$ N.	42	11	15

Lib-D4 (Detachable Data) System
Barcode Method's Patents (provisionally protected) U.S. Patents applied for

POINTS OF THE COMPASS—Continued

NAVIGATION

629.13.0042

				Points.	Angle with Meridian.	
					Degs.	Mins. Secs.
N.E.	-	N.W.	-	4	45	0
N.E., $\frac{1}{2}$ E.	-	N.W., $\frac{1}{2}$ W.	-	4 $\frac{1}{2}$	47	48 45
N.E., $\frac{1}{4}$ E.	-	N.W., $\frac{1}{4}$ W.	-	4 $\frac{1}{4}$	50	37 30
N.E. by E., $\frac{1}{4}$ N.	-	N.W. by W., $\frac{1}{4}$ N.	-	4 $\frac{3}{4}$	53	26 15
N.E. by E.	-	N.W. by W.	-	5	56	15 0
N.E. by E., $\frac{1}{4}$ E.	-	N.W. by W., $\frac{1}{4}$ W.	-	5 $\frac{1}{4}$	59	3 45
E.N.E., $\frac{1}{4}$ N.	-	W.N.W., $\frac{1}{4}$ N.	-	5 $\frac{1}{2}$	61	52 30
E.N.E., $\frac{1}{2}$ N.	-	W.N.W., $\frac{1}{2}$ N.	-	5 $\frac{3}{4}$	64	41 15
E.N.E.	-	W.N.W.	-	6	67	30 0
E.N.E., $\frac{1}{4}$ E.	-	W.N.W., $\frac{1}{4}$ W.	-	6 $\frac{1}{4}$	70	18 45
E.N.E., $\frac{1}{2}$ E.	-	W.N.W., $\frac{1}{2}$ W.	-	6 $\frac{1}{2}$	73	7 30
E. by N., $\frac{1}{4}$ N.	-	W. by N., $\frac{1}{4}$ N.	-	6 $\frac{3}{4}$	75	56 15
E. by N.	-	W. by N.	-	7	78	45 0
E. by N., $\frac{1}{4}$ E.	-	W. by N., $\frac{1}{4}$ W.	-	7 $\frac{1}{4}$	81	33 45
E., $\frac{1}{2}$ N.	-	W., $\frac{1}{2}$ N.	-	7 $\frac{1}{2}$	84	22 30
E., $\frac{1}{4}$ N.	-	W., $\frac{1}{4}$ N.	-	7 $\frac{3}{4}$	87	11 15
E.	-	W.	-	8	90	0 0

Magnetic Variations

Greenwich	-	-	15° W.	Cairo	-	-	2½° W.
Paris	-	-	13° „	Constantinople	-	-	1½° „
Brussels	-	-	12½° „	Salonika	-	-	4° „
Berlin	-	-	8° „				

An Approximate Method of Finding True North is as Follows:—

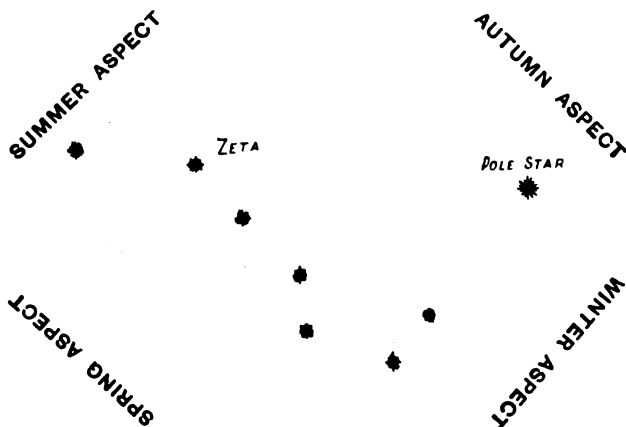
In the Northern Hemisphere.—Hold the watch horizontally, face upward, and point the hour hand at the sun. Then a line from the centre of the dial to a point half-way between the figure XII. and the hour hand will be approximately a south line.

In the Southern Hemisphere.—Hold the watch as above, but point the line from the centre of the dial to the figure XII. at the sun. Then the line found as above is approximately a north line.

It should be remembered that the method is a rough one, and becomes almost useless as the tropics are approached, although more reliable for higher latitudes.

To Find True North by the Stars

The “pointers” of the Great Bear are in a line with the Pole Star, as shown in the sketch.



SIGNALLING

629.13.0042

The Great Bear revolves about the Pole Star, so that it will be found lying in different positions at different times; when it is so placed that the star "Zeta" is either directly above or directly below the Pole Star, the direction of the latter is true north. At other times there is a small error, which at its greatest amounts to about $1\frac{1}{2}^{\circ}$.

SIGNALLING

629.13.018

A knowledge of signalling will be very useful to the aeroplane scout. The following outline is intended as a guide to the civilian who wishes to become conversant with this means of communication. The methods now in use in the Army mainly depend on the ordnance Morse or dot and dash alphabet, whether the signal be transmitted by flag or other means, such as lamps, heliograph, or field telephone (which is often employed as a telegraph for signalling). The semaphore system is still occasionally employed. Both the Army and Navy now only employ the "long" or full numerals to avoid any possible confusion. Certain technical differences occur in the Indian Army system, but they are not of such a nature as to present any obstacle in the way of Indian trained men from working with home trained signallers.

When transmitting Morse signals by flag, a single flag (instead of two flags, as is the case in the semaphore system) is pivoted in both hands held at a ready position (at about 45° to the horizontal over the left shoulder of the signaller). All signals are made from this ready position. The pole of the flag is so held that the hands come in front of the sender's mouth, and so that he can see beneath the flag. From the ready position, the pole of the flag being pivoted in the right hand, the flag is moved across the body to a corresponding angle on the opposite side, and is then brought back again to the first or ready position. This movement represents one dot. The dash signal is made by bringing the flag across the body until the pole is just below the horizontal, and then back again to the ready position.

In the diagram herewith the Morse International Code is given. The alphabet only differs from the Army modification of the code in that all the accented letters and "ch" are omitted in the latter. There are, however, considerable differences in the punctuation signs and signals, so these are given separately.

MORSE INTERNATIONAL CODE

a	— — — —	h	— — — —	q	— — — — —
ä	— — — — —	i	— —	r	— — — —
á or ä	— — — — —	j	— — — — —	s	— — — —
b	— — — —	k	— — — —	t	— — — —
c	— — — —	l	— — — —	u	— — — —
ch	— — — — —	m	— — — —	v	— — — —
d	— — — —	n	— — — —	w	— — — —
e	— —	ñ	— — — — —	x	— — — —
é	— — — — —	o	— — — —	y	— — — —
f	— — — —	ö	— — — —	z	— — — —
g	— — — —	p	— — — —		

FIGURES

1	— — — — —	4	— — — — —	7	— — — — —
2	— — — — —	5	— — — — —	8	— — — — —
3	— — — — —	6	— — — — —	9	— — — — —
		0	— — — — —		

SHORT FIGURES

1	— — — —	4	— — — — —	7	— — — — —
2	— — — —	5	— — — — —	8	— — — — —
3	— — — —	6	— — — — —	9	— — — — —
		0	— — — —		

PUNCTUATION

(.)	— — — — —	(l)	— — — — —
(;)	— — — — —	(')	— — — — —
(,)	— — — — —	(-)	— — — — —
(:)	— — — — —	(/)	— — — — —
(?)	— — — — —	(=)	— — — — —
(")	— — — — —	()	— — — — —
(")	— — — — —		

VARIOUS SIGNS

CALL	— — — — —
UNDERSTOOD	— — — — —
ERROR	— — — — —
END OF TRANSMISSION (+)	— — — — —
INVITATION TO TRANSMIT	— — — — —
WAIT	— — — — —
"RECEIVED" SIGNAL	— — — — —
END OF WORK	— — — — —
UNDERLINE	— — — — —

SPACING AND LENGTH OF SIGNALS

(1) A dash or bar is equal to three dots in duration of time or space; (2) the space between the signals which form the same letter is equal to one dot; (3) the space between two letters is equal to three dots; (4) the space between two words is equal to five dots.

It will be noted that this system has a harmonic or time basis, which is decided upon by the time required for a dot; intervals between letters or words are essentially definite multiples of the dot time, hence if careful attention is paid to the timing, a very clear system of signalling is available.

It must also be observed that in the International system the dot of former practice has been replaced by a short bar, as being more consonant with the time basis of the present-day system.

ARMY PUNCTUATION SYMBOLS

(Note.—These differ from the Morse International Code)

Full stop (.)	- - - - -	• — • — • —
Break signal or fresh line	- - - - -	— • • • —
Apostrophe (')	- - - - -	• — — — • •
Hyphen (-)	- - - - -	— • • • —
Exclamation (!)	- - - - -	— — • — —
Oblique stroke (/)	- - - - -	• — • • —
Horizontal bar or fractional bar (—)	- - - - -	— • • — •
Interrogation (?)	- - - - -	• • — — • •
Inverted commas ("")	- - - - -	• — • • — •
Brackets } }	- - - - -	• — — — • —
Underline	- - - - -	• • — — • —

MISCELLANEOUS ARMY SIGNALS

General answer	- - - - -	—	
Erase (part of message or a word)	• • • • •	• • • • •	
Obliterate (whole of message)	• — — • — —	• — — • — —	
Stop sending (P P)	• — — • — — •	• — — • — — •	
To indicate block capitals (Z)	— — • •	— — • •	
Repeat (I M I)	• • — — • •	• • — — • •	} For checking purposes
Word after (W A)	• — — • — —	• — — • — —	
Word before (W B)	• — — — • • •	• — — — • • •	
Go on or spell out (G)	— — •	— — •	
End of message (V E)	• • • — •	• • • — •	
Received correctly (Rd)	• — • — • •	• — • — • •	
Wait (M Q)	— — — — —	— — — — —	
Call or station call	• • • • •	• • • • •	
Symbol used between whole numbers and fractions (M M)	— — — — —	— — — — —	

“Code” Time (as used by all Army signallers) is the method adopted for signalling time, and is the most expeditious system yet discovered.

The 12 hours from 1 in the afternoon to midnight, and from 1 in the morning to midday, are denoted by the letters A to M omitting J. Thus :—

A denotes 1	E denotes 5	I denotes 9
B „ 2	F „ 6	K „ 10
C „ 3	G „ 7	L „ 11
D „ 4	H „ 8	M „ 12

The same letters stand also for the twelve periods of 5 minutes.

So A stands for not only 1 o'clock, but 5 minutes past any hour.

And B stands for not only 2 o'clock, but 10 minutes past any hour.

And C stands for not only 3 o'clock, but 15 minutes past any hour, e.g., B F means 2.30.

The intermediate minutes are indicated by the letters R, S, W, X, so that M R indicates 12.1, M X means 12.4, M A R means 12.6.

The letters “A.M.” and “P.M.” are always entered and sent in conjunction with the above.

Prefixes form a very important part of the curriculum of the signaller, and are consequently of interest here.

Messages are *prefixed* to serve the purposes of giving precedence of dispatch to those of highest importance, also to indicate whether they are to be transmitted or delivered in the case of station work. If a message contain X it is to be transmitted, if S it is for delivery.

Prefixes are *always* signalled at commencement of message.
The following are the British Army prefixes arranged in order of precedence:—

Messages to be Delivered at Receiving Station.	Messages to be Transmitted at Receiving Station.	Class and Remarks.
$\left\{ \begin{array}{c} \text{S O S} \\ \text{G A S} \\ \text{Z E P} \end{array} \right\}$ D S S B S G S M S S R P S P	D X X B X G X M X X R P X P	Take precedence over all, and to receive immediate attention.
		Signal service messages requiring immediate attention.
		Messages "O.H.M.S." marked "Priority."
		Signal service messages. Messages "O.H.M.S." not marked "Priority."
		Private messages. Reply paid messages. Press messages.

Memorising the Morse System.—The Morse system is not an easy one to memorise quickly, but by the application of mnemonics the task can be greatly facilitated. Commence with the "dot" letters: one, two, three, and four dots represent E, I, S, H respectively. The "dash" letters, one, two, and three dashes, are T, M, O respectively. Take next the combination of a "dash" with dots: — • • • (B), — • • (D), — • (N). (These, it will be noted, are in alphabetical order.) — • (N) may be associated with its opposite, • — (A), or by selecting the signals with a single "dash" at the end, the following group together, • — (A), • • — (U), • • • — (V), (again in order of alphabet). So far, half the alphabet is dealt with.

• — — — (J) is not easy to remember, but might be classed with signals commencing with a single "dot," viz., • — (A), • — — (W), • — — — (J). P (• — — •), having a dot at each end, and an equal number of dashes in the middle, is easily remembered, as is also Z (— — • •), two longs and two shorts. The opposites, K (— • —) and R (• — •), present no trouble. Other letters of a more difficult character are often learned after the memorising method of the medical student, i.e., by a "tag." A correspondent in *Aeronautics* gives the following examples:—

F (• • • — •). (Will you *miss* me?)

L (• — • •). (Now *don't* do it.)

G (— — •) and the opposite, W (• — —), the initials of Grahame-White.

X (— • • —). (*Excellent beer.*)

The figures are easy to memorise, as they go in numerical number of dots to five, and continue from six to naught in dashes.

Another method is to allocate a word with initial letter, number, and arrangement of long and short syllables that correspond to each Morse signal. Such a system, known as "Morse Made Easy," is published by the Wireless Press, Ltd., at Marconi House, Strand, W.C.

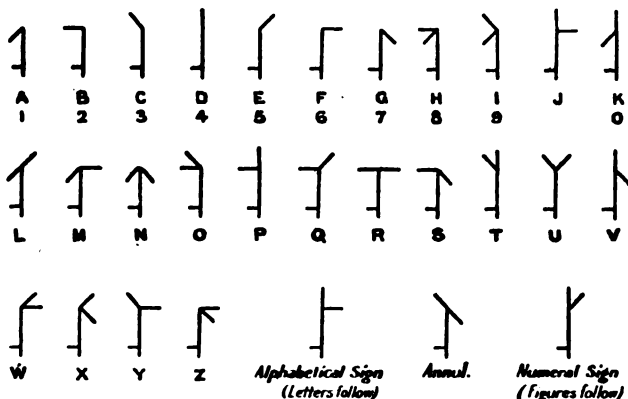
To minimise the confusion of similar sounding letters the following pronunciations are adopted for Army signallers:—

a=ack; *b*=beer; *d*=don; *m*=emma; *p*=pip; *s*=esses;
t=tock; *v*=vie.

Cipher Messages.—In decoding, if the key is unknown, it is useful to know the comparative frequency of different letters in various languages. The following gives the letters in order of frequent occurrence:—

English	-	-	-	E (12 per cent.)	TAONISRH.
French	-	-	-	E (18 per cent.)	SANTIRUL.
German	-	-	-	E (14 per cent.)	IVIRSTUDA.

SEMAPHORE ALPHABET



The small arm on the left of the post is the "indicator," and is used to show from which side the signals are to be read. In the foregoing alphabet the signaller and the reader are facing each other. When sufficient practice has been obtained the signals can be read with equal clearness whether the signaller has his back or face to the reader. Figures are distinguished by being preceded by the "numeral sign" and followed by the "alphabetical sign." They are checked by being repeated back from the reader to the signaller.

AIRCRAFT AND NAVIGATION INSTRUMENTS

Various instruments are useful, and some indispensable, for long cross-country flights. The most important are the following:—

Tachometer, or engine revolution indicator (see pp. 384, 531, 775).

Oil pressure gauge } (see 621.431.3.0244).

Fuel pressure gauge }
 Altimeter or aneroid barometer or barograph (see 533.331).

Compass (see 538.74).

Clinometer (see 629.13.0552).

Air-speed indicator (see 629.13.0552).

Clock or watch.

Among the instruments of lesser importance are distance indicators, lateral and longitudinal clinometers or angle of attack indicators, drift or navigation sight. Bearing plate, Darwin turning indicator, bubble statoscope, course and distance calculators, sighting apparatus for bomb dropping, sextant (designed for measuring the altitude of a heavenly body above a horizontal plane without the use of a sea horizon or an artificial horizon), fuel gauge, fuel flow indicator, oil gauge (on main tank), radiator temperature indicator, binoculars (preferably of the prism or else of the microscope eye-piece type), special aeroplane camera, gyroscopic stabilisers, rate of climb meters, statoscopes, etc.

Weights of Instruments.—About 8 to 12 lbs. is usually allowed for the total weight of the instruments with which it is advisable that an aeroplane should be equipped. This is based upon an average of under 1 lb. per instrument.

Illumination of Dials.—As it is important that all instruments should be easily read at any moment, whether by day in an obscure corner, or by night, good illumination is essential. Two methods are in use: one is by the use of shaded miniature electric lamps, and the other by painting the dials with luminous paint, or radio-active substances. Luminous paint is made from compounds which absorb sunlight during the day and phosphoresce after dark. These are not very effective. Of the radio-active materials in commercial use, mesothorium and radium are the most important. Apparently only radium is practicable under service conditions, as the mesothorium deteriorates quickly. When at its best, however, mesothorium gives excellent luminosity.

A number of samples of radium luminous compound, as supplied by Watson & Sons, tested at the National Physical Laboratory, showed the following results when compared with the Admiralty Standard for material containing 0.4 milligramme radium bromide

per gm. of paint, which is taken as 100 for purposes of comparison :—

Grade.	Radium Content Conforms to Standard for	Radium Content.		Luminosity Compared with Admiralty Standard.
		Radium Element.	Radium Bromide.	
5	British Army Marching Compasses	0.10	0.2	110
6	U.S.A. Instruments for Hydro-aeroplanes	0.15	0.28	170
8	British Admiralty Compasses, etc.	0.215	0.4	210
10	Most suitable Grade for Aeroplane Instruments	0.3	0.56	240

Where electric lights are used, it is often convenient to switch them off, except when a reading is to be taken, as then there is no possible glare to distract the pilot's vision.

General Requirements.—It is essential that all aeronautical instruments should be as compact, light, and strong as is consistent with accuracy, ease of reading, durability, reliability, and water-proofness. They should also be free from the disturbing effects of acceleration errors, altitude, temperature changes, and vibration. (Unless, of course, the instruments are designed to measure any of these effects.)

Makers of aeronautical instruments generally incorporate special features in their own patterns, hence the field is too great to permit of a detailed description of each piece of apparatus; and further, constant improvements are being made. However, some notes on a few types follow herewith, as being of more special interest.

629.13.0531

Aero Course and Distance Calculators with time and distance scales used on aircraft for the rapid solution of the triangle of velocities and the determination of the time of flight for the purpose of navigation. Each instrument comprises a bottom disc of opaque celluloid calibrated with concentric azimuth and logarithmic scales, a top disc of transparent celluloid marked with a peripheral logarithmic scale and with its central portion squared and calibrated to indicate velocities per unit time, and two radial arms provided with cursors and similarly graduated. The two celluloid discs and the two radial arms are mounted on a common pivot in such a manner that they can be relatively rotated.

An Aero Bearing Plate with ground speed sights is used on an aeroplane :—

- (a) To indicate the amount of deviation or drift.
- (b) To estimate the ground speed.

The complete instrument comprises three relatively rotatable concentric rings. The middle ring constitutes the base plate, and is furnished with a securing bracket which engages a fixed shoe; the inner ring is in the form of a graduated dial, and the outer or sight-ring carries fore and back sights and a radius bar.

629.13.054

The **Clinometer**, also variously called an inclinometer, level, or gradometer.—This is an instrument which is employed to indicate the angle of inclination of an aeroplane in flight. The usual type consists of a form of spirit level, having a curved glass tube, sealed at both ends, and containing a non-freezing liquid and an air bubble. Pendulum devices are also in use. However, both these types, while they serve ordinary practical purposes, are affected in their indications by accelerations and decelerations. It would be of advantage to have an instrument that would overcome these defects, and further afford a base line for sighting in conjunction with navigation instruments, probably a gyroscopic principle of design would solve the problem.

A clinometer does not indicate the true vertical, unless the aeroplane to which it is fitted is flown in a straight line. Even then it is better to estimate whether the aeroplane was properly trimmed by looking out for side-slip. On a properly banked turn, the bubble remains central; evidence of the fact that the inward component of the lift of the planes towards the centre of the turn is exactly balancing the centrifugal effect. The bubble goes to one side when the aeroplane is not properly banked. The control column should then be moved in the same direction as the bubble, until the cold stream of air, which impinges on one side of the face, disappears. In fact, this latter indication is a far better guide to proper flying than the watching of a bubble.

An Aero Turning Indicator, with a swivelling static head, is used on aeroplanes to give an indication when the craft is deviating from a straight course and is flying on a curved path. The static head comprises a static tube, a conical vane to which the rear end of the static tube is secured, a supporting tube, which is attached to the static tube by means of a universal joint, and an attachment for securing the supporting tube to the main plane.

629.13.0552

The **Air-Speed Indicator** usually adopted is of the pressure head type. It consists of a pitot tube, a static tube, and a suitable indicator. The pressure head proper is mounted on one of the outer forward struts of an aeroplane, about two-thirds of the way

up, with the indicator on the switchboard—the necessary connections being made by aluminium piping.

Pitot Tube.—If a tube has one end closed and is so placed that the open end faces a current of air, it will be found that there is a higher pressure inside the tube than there is outside.

If p denote this excess pressure, d the density of the air, and v the speed of the air current, it is found that

$$p = kd v^2,$$

where k is a factor depending mainly upon the inclination of the open end of the tube to the air current (which may be called the angle of incidence).

Experiments show that if the angle of incidence is less than 10° , i.e., if the tube points less than 10° away from the correct up-wind position, the changes in k are negligible, but for greater angles they become very considerable.

It is clear that if the tube is kept facing up-wind, and if a suitable indicator is connected to the closed end, the apparatus could be used to measure either the speed of the wind when the instrument is at rest, or the speed at which the aircraft to which the instrument is attached is moving through the air.

The instrument will *not*, of course, indicate the speed at which an aeroplane is moving over the ground, since this depends on the speed at which the air is moving over the ground, i.e., on the strength of the wind.

Static Tube.—This is employed to obtain the average pressure outside the aeroplane, and so obviate errors due to any air disturbance vacuum in the fuselage. It is connected to the low pressure side of the indicator. It consists of a tube with the end closed to screen it from the effects of the air current; communication to the outer air is made through the medium of several small holes drilled in the side of the tube near the end.

The Indicator.—This consists primarily of two chambers, separated by a movable, air-tight diaphragm. One of these chambers is connected to the static tube and the other to the pilot tube. The difference of pressure on either side of the diaphragm causes the latter to move, and so actuate a mechanism which operates a suitable pointer.

Calibration.—Air speed indicators are calibrated to read correctly for a density d of air of 1,221 gms. per cubic metre. This corresponds to a barometer height of 29.92 in. (760 mm.) and temperature 16° C.

To correct readings for other densities, multiply by the factor

$$\sqrt{\frac{1221}{d}},$$

where

$$d = \frac{11795 h}{273 + t}$$

d = density in grammes per cubic metre ; h = inch of mercury ;
 t = deg. C.

The above factor is derived as follows :—

Since $p = k dv^2$
and the calibration density is 1,221 gms. per cub. m. by substitution—

$$p = k(1,221)V^2.$$

Where V is the indicated air speed ; hence $1,221 V^2 = dv^2$.

$$v = \sqrt{\frac{1221}{d}} V.$$

Air-speed indicators can be checked by aid of a water gauge.
For this purpose the following table is applicable :—

SPEED AND PRESSURE

1 knot = 1.1520 miles per hour.

1 mile per hour = 0.8680 knot.

Miles per Hour.		Knots.	
Air Speed in M.P.H.	Pressure Inches of Water.	Air Speed in Knots.	Pressure Inches of Water.
30	.44	30	.58
35	.60	35	.80
40	.78	40	1.04
45	.99	45	1.32
50	1.22	50	1.62
55	1.48	55	1.96
60	1.76	60	2.34
65	2.07	65	2.74
70	2.40	70	3.18
75	2.75	75	3.65
80	3.13	80	4.16
85	3.54	85	4.69
90	3.97	90	5.26
95	4.42	95	5.86
100	4.90	100	6.49
105	5.40	105	7.16
110	5.93	110	7.86
115	6.48	115	8.59
120	7.05	120	9.35
125	7.65	125	10.15
130	8.28	130	10.97
135	8.92	135	11.83
140	9.60	140	12.73
145	10.30	145	13.65
150	11.02	150	14.61
155	11.76	155	15.60
160	12.54	160	16.62

Isothermal Height (Feet).	Percentage Correction to be Added to Air-Speed Indicator Readings at Ground Temperature.				
	-10° C.	0° C.	10° C.	20° C.	30° C.
0	-4.6	-2.8	-1.1	+ .7	+ 2.4
1,000	-3.2	-1.3	+ .5	2.2	3.9
2,000	-1.7	+ .2	2.0	3.8	5.6
3,000	- .1	1.7	3.6	5.4	7.2
4,000	+1.4	3.3	5.2	7.0	8.8
5,000	2.9	4.9	6.8	8.6	10.5
6,000	4.5	6.5	8.4	10.3	12.2
7,000	6.1	8.1	10.1	12.0	13.9
8,000	7.7	9.8	11.8	13.7	15.6
9,000	9.4	11.4	13.5	15.4	17.4
10,000	11.0	13.1	15.2	17.2	19.2
11,000	12.7	14.8	16.9	19.0	21.0
12,000	14.4	16.6	18.7	20.8	22.8
13,000	16.2	18.4	20.5	22.6	24.7
14,000	17.9	20.2	22.4	24.5	26.6
15,000	19.7	22.0	24.2	26.4	28.5
16,000	21.5	23.8	26.1	28.3	30.4
17,000	23.4	25.7	28.0	30.2	32.4
18,000	25.2	27.6	29.9	32.2	34.4
19,000	27.1	29.5	31.8	34.2	36.4
20,000	29.0	31.4	33.8	36.2	38.5
21,000	30.9	33.4	35.8	38.2	40.5
22,000	32.9	35.4	37.9	40.3	42.6
23,000	34.9	37.4	39.9	42.4	44.8
24,000	36.9	39.5	42.0	44.5	46.9
25,000	38.9	41.5	44.1	46.6	49.1

In the above table the *isothermal height* is obtained by adding to the *altimeter height* the *isothermal height* of ground corresponding to the barometer height on the given day.

EXAMPLE.—Ground temperature, 20° C.; barometer height at ground level, 28.6 in.; air-speed indicator reading, 100 m.p.h.; altimeter reading, 9,800 ft.

The isothermal height of ground corresponding to 28.6 in., upon reference to barometric tables, will be found to be 1,208. The isothermal height of the aeroplane is therefore 9,800+1,208 ft., say 11,000 ft. From the above table, the correction to be applied (viz., at 11,000 ft. and a temperature of 20° C.) is 19 per cent. 19 per cent. of 100 m.p.h. = 19 m.p.h. The corrected air speed is therefore 119 m.p.h.

Use of Indicator.—When the aeroplane is brought head to wind, ready for flight, the indicator will show the speed of the wind. On taxiing, a reading will be observed which is a combination of the speed over the ground and the motion of the wind. When the indication reaches that of the minimum flying speed, the aeroplane will leave the ground, and the speed will increase still further. Then, and not till then, is it safe to pull the control column back, and so assist the aeroplane to rise. If the control column is pulled back before flying speed is attained, the incidence will be so great that the head resistance will slow it, until it stalls. When flying, the air-speed indicator should be kept under observation, so as to ascertain the best climbing speed. As the angle of incidence increases, the drag increases and the lift diminishes, the speed, therefore, falls. From this, it will be appreciated that the air-speed indicator practically replaces a longitudinal inclinometer. Every aeroplane has a particular angle of incidence at which it climbs best. This angle is best recorded as the angle corresponding to a particular air speed, or that the aeroplane climbs at a particular speed. When turning, it must be borne in mind that part of the lift of the aeroplane is employed in deflecting it from its course. The outcome of this is to reduce the speed range of the aeroplane, i.e., it stalls at a higher speed when flying straight. The stalling speed of an aeroplane should always be ascertained, and then the machine should be kept well above it when turning.

Stalling Speed.—The lift on a given aeroplane in steady, level flight, at a given angle of incidence, is proportional to dv^2 , where d is the density and v the true air speed. Since $dv^2 = 1,221 V^2$, where V is the indicated air-speed, this makes the lift proportional to V^2 . If V falls below a certain value, the aeroplane will stall. This value of V is independent of the density—in other words, the aeroplane, in straight, level flight at a given angle of incidence, will always stall at the same *indicated* air speed, whatever the height. This close correlation of air-speed indicator readings with the performance of the aeroplane is one of the most valuable characteristics of the instrument, and would be lost if it were made to show actually the true air speed at all densities. It should be borne in mind that the stalling speed on turns is higher than in straight flight, consequently the aeroplane will stall more easily, and the air speed must be more carefully watched when turning and a margin of air speed above the ordinary stalling speed must be allowed.

629.13.059

Flow Meter.—For test purposes the Cowey type is employed. It consists of a glass tube of about $\frac{1}{2}$ in. diameter, with a floating ring inside. The position of the ring indicates the rate of flow, say 1.14 gals., or 7.25 gals. per hour. A considerable head of power is

absorbed in these instruments, hence they are not suitable for gravity feed installations.

531-775

The Revolution Indicator indicates the rate of revolution of the crankshaft of the engine to which it is attached. The actual instrument is mounted on the instrument board, and is driven by means of a flexible shaft and suitable reduction gears. Owing to the trend of engine design being to obtain as much power as possible at high altitudes, if care is not taken, such engines will race, and so get seriously damaged, if opened out too much at ground level. Hence it is important to keep the revolution indicator under close observation. The output in horse-power is proportional to the revolutions per minute, hence an idea as to the power developed by an engine can be obtained by watching the indicator.

The principal forms of revolution indicator are the centrifugal weight type (Elliott, Watford, etc.); escapement type (Tel, Jaeger, etc.); magnetic type (Warner, etc.); electric type (Elliott, German, etc.). At the present time the centrifugal type is the most frequently used pattern.

D.E.D.A. (Detachable Data) System
K. B. & C. Matthews Patents (provisionally protected) U.S. Patent applied for

AERO CLUBS AND SOCIETIES

OWING to the War and the early stages of demobilisation, most of the clubs are still quiescent, hence no useful purpose will be served by reprinting their names and addresses. For the latter the reader is therefore referred to the 1916 edition of the "AVIATION POCKET-BOOK."

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The paramount purpose of this organisation is to urge upon the people of this country, the Government, and Members of Parliament the vital importance of adequate aerial forces.

THE AVIATION POCKET-BOOK 629.13.(062)

It has commenced the issue of its own news sheet for the purpose of providing its members with a record of the League's transactions and the most notable features of the world's activities in aeronautics.

The League is taking the initiative in an air flight to Australia, in order to demonstrate the stability and long flight capabilities of British made aircraft, and to carry into practical effect the following recommendation of the Government Aerial Transport Committee:—

“As an urgent necessity, the establishment of a system of propaganda throughout the Empire in order to convince the whole nation of the vast importance or possibilities of aerial transport, and to familiarise the Governments and Local Authorities with the subject. There is evidence of such a system in enemy countries.”

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AEROPLANE ALIGNMENT AND RIGGING

Erection Jigs and Fixtures—Aeroplane Alignment—Tautness Meters—Manufacturer's Order of Erection—Detailed Procedure for Alignment—Checking of Centre of Gravity—Inspection after Flight—Useful Knots.

ERECTION jigs and fixtures for turning out aeroplanes complete and ready for flight are very little employed at present, though it is anticipated that their use will be considerably extended in future. Until these time and labour saving devices are instituted, erection, alignment, and rigging must be carried out in the ordinary way, largely dependent on the skilled judgment of the staff employed on the works or in the field.

(Further particulars of jigs and fixtures will be found at the end of the Division dealing with Aeroplane Design.)

AEROPLANE ALIGNMENT

As an aeroplane is essentially a stayed structure, all adjustments made to secure alignment must be carried out very methodically. If possible, an erection drawing should be obtained of the particular machine to be aligned. The drawing should be very carefully followed. The importance of good rigging cannot be over-estimated, as otherwise an aeroplane will not give its best performance, and may be dangerous to fly. An outline is given herewith of a good general scheme to be followed for lining up an aeroplane, a more detailed account of the procedure being given later :—

(1) Support the body rigidly on two or more trestles in such a way that the datum line on the erection drawing is horizontal. If the aeroplane to be trued up is complete it should be securely supported by a trestle under a pair of struts at the tail, and by small trestles or chocks under the undercarriage struts. This line is often indicated on the fuselage by horizontal marks on the vertical struts. The top and bottom struts of the fuselage should, of course, also be horizontal. True up the body to the datum line.

(2) Adjust the undercarriage if required. The operation depends very largely on the design of the undercarriage.

(3) Align the main planes, commencing with the centre main top plane, if fitted. Correct the dihedral, the incidence, and finally the stagger.

- (4) Check the attitude of the tail plane, and the fin or the rudder with the body and the main planes.
- (5) Set the controls.

The Appliances required for truing up a machine depend on the method used. Measurements may be taken either by protractor level, i.e., in degrees, or by measurement of the linear deviation from set vertical and horizontal datum lines. Usually the methods are as follows:—

- (1) The dihedral is measured in degrees from the horizontal with a linear check measurement.
- (2) The incidence is given as the angular dimension with the horizontal made by a straight-edge held against the leading and trailing edges. Before making any of these measurements the aeroplane should be in *flying position*, usually with one pair of longitudinals level, or with the datum line of the body level.
- (3) The stagger is a linear measurement giving the distance the leading edge of the top plane is in advance of the leading edge of the bottom plane.

A spirit-level protractor with Vernier reading (usually to 10') in combination with a good wooden straight-edge is used for angular measurements.

A number of engineers' plumb bobs and a steel rule divided into $\frac{1}{4}$ in. or $\frac{1}{8}$ in. are used for measuring the stagger, etc.

A steel tape about 50 ft. in length, divided into $\frac{1}{8}$ in., $\frac{1}{16}$ in. (or into millimetres if the dimensions are given in the metric system), is required for long measurements.

Special adjusting rods are sometimes used for checking the gap or other similar dimensions.

The makers of various machines have developed certain forms of special gauges, jigs, or clips, particulars of which are often given on erection drawings.

After taking a measurement, it is advisable to take a check measurement where possible.

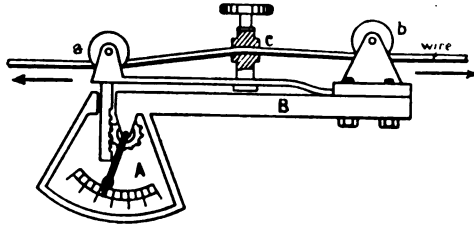
Tautness Meter.—A useful instrument was described by Lt.-Col. Mervyn O'Gorman, C.B., in a paper on "Problems Relating to Air-craft." This is made by the Cambridge Scientific Instrument Company, and permits of measuring the tension of any wire without cutting it. Its use has eliminated many an accident.

The principle of the appliance is that if a wire be stretched between two fixed points, a pull is required to deflect or bend it, and this pull is a measure of the stretching force. For this purpose the stretched wire rests on two rollers at *a* and *b* respectively, and is clamped gently at *c*.

The two rollers and the clamps are not a straight line, therefore the stiff spring to which they are attached is deflected, and the amount of this deflection is measured on a direct reading dial

graduated in lbs. A helical spring is substituted for the flat spring shown in the illustration in the latest instruments.

A modification of this appliance is employed to measure the tension on the cables attached to a captive balloon. It is also made



in the form of a recording instrument. For use in the erection of machines on jigs and fixtures, special forms have been devised, each of which is kept apart for testing certain wires or sets of wires under equal tension. In this case a red line is put on the dial to indicate the point of correct strain.

An entirely different form of instrument consists of a row of steel springs, of varying lengths, mounted on a metal base. The wire to be tested is twanged by hand, and the body of the instrument brought in contact with one end of the wire. The steel spring, whose period of vibration corresponds to that of the wire under test, will vibrate in unison. From a previously prepared scale or table the strain on the wire can then be ascertained. This principle has been employed previously for steam engine tachometers, where it had the advantage that no drive had to be provided.

Manufacturer's Order of Erection.—This largely depends upon the type and design of the aeroplane. However, the following will serve as a guide to modern practice :—

1. Assemble and fit up the **fuselage**. Very often, especially in the larger machines, the front and rear portions are erected separately, and then joined together and lined up.
2. Fit **tail skid**, and tail plane actuating gear, if the aeroplane is fitted with the latter.
3. Fix front **engine plate** or engine **bearers**.
4. Place **controls** in position, in front of the fuselage.
5. Install **main petrol tank**. This is occasionally delayed until the centre section and undercarriage are fitted.
6. Attach the **undercarriage**.
7. Fit **centre section**.
8. **Complete the work on the fuselage** by fixing the dash-board, instrument-board, decking, fairing, etc. The controls in front of the fuselage are often added at this juncture, instead of after fitting the engine supports.

9. **Mount the engine** in the aeroplane in its flying position. The engine cowling is sometimes fitted at this stage. Also the engine accessories and controls.

10. Attach the automatic **gun operating gear**.

11. Bolt the **oil tank** in position.

12. Put the **radiator** and radiator cowling in place.

13. Connect up the **pipings** and wiring service for oil, petrol, water, and electricity.

14. Attach the **main planes**, struts, etc., with the machine in flying position.

15. Erect the **tail unit**.

16. Connect and adjust the **controls**. Fit the petrol tanks, if not previously done.

17. Remove main planes for covering with fabric and doping, if not already done before erection. **Cover and dope the fuselage**.

18. Affix the **gun mounts**, magazines, chutes, etc. Fit the engine cowl if not already in place.

19. **Adjust the controls** first for the rudder and elevators, and then for the ailerons.

DETAILED PROCEDURE FOR ALIGNMENT

Alignment of Fuselage.—Level the fuselage longitudinally and transversely by aid of a spirit level, supporting it on two suitable trestles. Place, or lightly clamp, a straight-edge across the front in a horizontal position. Mark the centre, and set off a couple of equidistant points on either side. From these latter points make measurements to a few corresponding points along the sides of the fuselage, and adjust the bracing until the measurements on either side are equal and the whole fuselage symmetrical. Mark points along the side struts, these points to be along the datum line. Clamp a straight-edge across the marked points of a pair of foremost struts and one across the marked points of a pair of rear-most struts. The actual struts to be selected, to be decided from considerations of accessibility. Stretch a line from the forward part of the front straight-edge to the end point of the rear straight-edge. This line will be the centre line of the fuselage.

An alternative method is to drop a plumb line from the nose of the engine and from the stern post. Stretch a string between these two points. Plumb bobs dropped from the centres of the horizontal struts should lie on this line, in which case the fuselage is now true in plan view.

To true up inside view, reference must be made, if possible, to an erection drawing, when a horizontal datum line should be found. The position of the intersection of the vertical struts with this line should be given on the drawing. Set off these points on the struts and adjust to a string stretched horizontally passing through the extreme points.

To sum up, if the fuselage is to be symmetrical in both plan and

elevation, the great thing to aim at is to true it up in such a way that (1) the middle points of all cross struts, top and bottom, are in one vertical plane and (2) the middle points on all side struts are in one horizontal plane. Where a fuselage is constructed in two or more parts, the longerons of the front and rear sections are usually joined by butt joints and fish plates. It must be borne in mind that the front portion of many machines is symmetrical in plan view only. In making adjustments in a two-part fuselage, it is well to work from the junction of the front and rear portions.

When the internal cross bracing wires have been adjusted, they should be checked with the aid of a trammel, to make sure that the diagonals are equal. If a stretched string is used as a gauge for horizontal lines, it should not touch any of the struts, or other parts between its points of support. A try-square should be used for checking alignment.

It is a very good plan to employ three stretched strings in alignment—one about the centre of the fuselage, and two (one on either hand) along the datum line or marked points on the side struts of the fuselage.

After the internal cross bracing wires, the top cross bracing wires should be tightened, until the middle points of the top cross struts are in line in plan view. This should be checked by a try-square. Then the cross bracing wires on *one* side should be adjusted, until the middle points of all the side struts in the rear portion are in line with the marked points (if the fuselage is not symmetrical) of the front portion. Again check with the try-square.

To complete the adjustment of the cross bracing, place a straight-edge across the fuselage near the end. Then take another and place it consecutively near each cross strut (clear of the strut fittings). Then tighten the hitherto unadjusted side cross bracing, until both straight-edges are in line, sighting at all points to see that there is no wind in the fuselage.

Finally, tension the bottom cross bracing wires. The fuselage should then be quite true, but should receive a last test all over by means of the try-square with reference to all lines. It is very important that bracing wires should not be overtightened, as this sets up unnecessary compression stresses in the struts and longerons.

All bolts on the fuselage should be burred over after truing up. On all wires where turnbuckles occur, the threaded portion must be fully engaged inside the barrel. If lock-nuts are employed (which is not good design) care must be taken not to tighten them too much; use should be made of a very small spanner, or the wires may break, possibly in flight.

It is taken for granted, that in the first place, all tie rods or wires have been accurately made to length, or else a good deal of trouble will arise in truing up the fuselage.

The rudder post must be vertical, viewed from any direction, once the fuselage has been trued up. This must be continually checked during the process of alignment. Also a continual watch

must be kept on the level of the spars at the bottom of the fuselage, which form the attachments for the bottom main planes.

The **flying position** of the machine should next be verified, longitudinal adjustments being made by raising or lowering the tail, and transverse ones by packing blocks under the undercarriage struts.

No very special precautions have to be taken in the fitting of the tail skid. It should be seen that no bracing wires foul or jamb its free operation. If of the steerable type, it must operate freely, and levers, etc., must be well clear of the fuselage members.

It is usual to fit the tail plane actuating gear, so that when the lever or front portion of the wheel at the pilot's side is raised, the leading edge of the tail plane is depressed, and vice versa. The tail plane should be set so that when the tail plane actuating lever or wheel is in its neutral position the tail plane is also in its neutral position. Both these positions are specified by the makers.

The actuating cables should be kept fairly taut. If bell crank levers are fitted in pairs, they must be checked for parallelism and alignment. It should be seen that split pins are inserted (and opened out) where necessary, and that all turnbuckles are locked.

Truing up Undercarriage.—Adjust the front cross bracing wires until the corresponding diagonals are equal. Verify by means of a trammel. The axle must be exactly normal to the centre line of the body. Check the whole undercarriage for symmetry by aid of plumb lines placed at equal distances from each side of the fuselage. A front strut on one side of an aeroplane must be in line with the rear strut on the same side of the machine. Split pins must be properly fitted on detachable parts, and the bolt ends of fixed parts must be burred over. All cables should be moderately tight.

Alignment of the Main Planes.—The following procedure is given for a tractor biplane, as the most generally used type of machine, but if the principles of the method are grasped, no difficulty will be experienced in truing up the planes of a monoplane or triplane.

Centre Main Plane.—The upper centre main plane struts are usually first bolted to this portion, which is then lifted into position. The lower ends of the struts are next attached to their fittings on the top longerons of the fuselage. The cross bracing wires (for side to side adjustment) are then loosely connected, also the ends of the main plane landing wires. Longitudinal adjustment of this portion is made by aid of the front drag and rear anti-drag wires, or failing these by the side cross bracing wires. Transverse adjustments are carried out by means of the front cross bracing wires. The stagger, if any, must be ascertained, and set with the help of a plumb line. The centre main plane should be symmetrical about the vertical centre line of the machine; this should be verified

by plumb lines, and the diagonals by trammels. The correct incidence for the upper centre main plane should be ascertained, and adhered to carefully. It should be tested by aid of a straight-edge across the leading and trailing edges, and an Abney or other similarly accurate angle measuring spirit level. After truing the centre section, it is a common practice to fit the gravity or service tank, if it is to be attached to this centre section.

Main Planes.—These are either assembled as a complete unit, one side at a time, or else the bottom plane is first fitted. By the former method, all the struts and wires are loosely connected beforehand. The set is then lifted into position, supported by trestles at the main plane skids, bolted to the centre section planes (fitting spring washers and split pins), and finally the landing and drag wires are joined up.

When the bottom plane is first put into position it is supported on a trestle at the outer end, and the inner side is bolted to the fuselage. The landing wires are next loosely connected in the inner bays. By means of the interplane struts, the top main plane is lifted into position, by inserting the bottom end of the struts into their sockets on the bottom main plane, and then bolting the top main plane to the top centre section plane. All the remaining interplane wires are then loosely connected, likewise the drag wires.

About six plumb bobs are then dropped from the leading edges of the top main plane, three on each side, and adjustments made until all six are in line, when viewed from the side.

Dihedral.—The following step is to check the *dihedral*. This angle is set either by means of a straight-edge and level along the spars, or by stretching a line from plane tip to plane tip, and measuring its height above the top of the front spar of the centre main plane—this being a given measurement. The incidence, front landing wires should be employed to adjust this angle.

The front spars should now be in their correct position, which is the first object to be aimed at in alignment. The rear landing wires should next be adjusted until the dihedral angle is approximately the same along the front and rear spars.

Incidence.—This angle is usually constant, though it may vary. It is set by adjusting the flying and landing wires of the rear spars only. As in the case of the centre section, it should be checked with a level by aid of a straight-edge across the leading and trailing edges.

The incidence is often increased by about one degree at the outer strut of the port bottom plane, to allow for airscrew torque. Very often, however, neither wash-in nor wash-out has to be provided for.

Stagger.—To be checked in the same way as the centre main plane.

Setting the incidence of the lower plane automatically sets the

incidence of the top plane, and also fixes the dihedral of the rear spar. Both these measurements should, however, be independently checked. When the dihedral angle and the incidence are correct, the stagger will also probably be right, provided that the centre main plane portion was correctly trued up. If not, such slight adjustments as may be necessary can be made on the incidence or stagger wires, when finally tensioning the latter. It should be noted that these wires serve to finally brace up the main planes, and should not be used for making direct adjustments.

Gap.—This should be measured by a vertical lath touching the leading edge of the top plane, and a levelled straight-edge from the leading edge of the bottom plane to the lath.

Sweep-Back.—This is checked in similarly to the stagger, as carried out on the centre section, only to a given measurement at a given point (or at a given angle to the normal to the fuselage centre line).

To ensure that the planes are *square* with the fuselage, measurements are taken from some point on the extremity of the main planes, or from the bottom front strut sockets, or the bottom outer wiring plate, and to the engine nose, and similarly to the rudder post. Measurements are also taken from the tail plane extremities to similar points on each side of the fuselage.

The dimensions b , b should not have a variation of more than $\frac{1}{4}$ in. in 20 ft. The dimensions a , a , $\frac{1}{4}$ in. in 20 ft. c , c varies greatly with the size of the tail, but it should approximate in accuracy to a , a .

Another check is to measure the distance from the centre of the front outer strut to the front bolt on the drag wire wiring plate in front of the fuselage.

Caution.—While the adjustment of the main planes has just been described in stages, it must be noted that in practice the dihedral angle, incidence, and the stagger should be continuously checked, the one against the other, for any alteration to one may alter slightly the adjustment of the others. The method outlined obviates this difficulty as far as possible.

The front drag wires should be connected up when the truing of the main planes is completed.

Tail.—The usual course is to fix, firstly, the fin in position, and secondly, the tail plane. The bracing wires between them are then attached. Next the tail plane spars are trued by aid of a spirit level until they are horizontal, and the fin post adjusted, with a plumb bob, until the rudder hinges are vertically one over the other.

The tail plane is tested for squareness by check measurements from points on the extremities to some fixed point on the fuselage, say the gun pivot on the gunner's platform; also to the rear outer struts. The rudder and elevators are then attached, and made secure by fitting split pins.

Rigging of Controls.—When rigging controls of an aeroplane the following is a good scheme to follow :—

1. Lash rudder bar in such a position that it is square with and across the fuselage.

2. Lash the pilot's control column in a vertical position. (Unless some other position is specified on the rigging diagram.)

3. Connect up the rudder control cables, and adjust them by means of the turnbuckles with which they are provided, until the rudder is pointing directly fore and aft, in line with the centre line of the aeroplane.

4. Adjust the compensating aileron control cable by means of its turnbuckles, until the ailerons have their correct droop.

(By this latter expression is meant the distance the trailing edge should be below the trailing edge of the main planes. This droop is always specified on the rigging diagram.)

5. Adjust the aileron gap wires so that the top and the bottom ailerons have the same and correct droop.

6. Connect up the aileron control wires and adjust the latter until they are just taut.

7. Connect up the elevator control wires and adjust until the elevators are in streamline continuation with the tail plane. (Unless any other position is specified on the rigging diagram.)

8. If the aeroplane is provided with skid controls, these should be rigged similarly to, and in conjunction with, the rudder.

9. In the case of an aeroplane provided with a tail plane adjustment gear, it is usual to set the tail plane in a mean position. (Unless other instructions are given on the rigging diagram.) The control elevator or wheel which actuates the tail plane adjusting gear is then also set in its mean position, and the control cables correspondingly adjusted.

10. When the above operations have been completed, the rudder bar and pilot's control column should be unlashd, and a check made of the movement of all the controls in all directions to see that the range of movement is correct.

The Setting of the Controls is the final stage of the adjustments. First the rudder bar must be fixed in a central position, and also the rudder, while the control wires are adjusted. The next step is to fix the elevator in line with the tail, so as to be in the neutral position. At the same time the control lever is fixed temporarily in the normal, usually vertical, position for flying. The elevator control cables can then be adjusted. The control lever should next be temporarily fixed in a vertical position, and the ailerons placed in the neutral position, a little below the trailing edge of the main planes to allow for the sag in the wires. After this the cable or cables on the top plane should be connected up, followed by the connection of the other control wires.

The bottom elevator control wires must be left fairly slack. When the pilot's control column is vertical, the ailerons generally,

incidence of the top plane, and also fixes the dihedral of the rear spar. Both these measurements should, however, be independently checked. When the dihedral angle and the incidence are correct, the stagger will also probably be right, provided that the centre main plane portion was correctly trued up. If not, such slight adjustments as may be necessary can be made on the incidence or stagger wires, when finally tensioning the latter. It should be noted that these wires serve to finally brace up the main planes, and should not be used for making direct adjustments.

Gap.—This should be measured by a vertical lath touching the leading edge of the top plane, and a levelled straight-edge from the leading edge of the bottom plane to the lath.

Sweep-Back.—This is checked in similarly to the stagger, as carried out on the centre section, only to a given measurement at a given point (or at a given angle to the normal to the fuselage centre line).

To ensure that the planes are *square* with the fuselage, measurements are taken from some point on the extremity of the main planes, or from the bottom front strut sockets, or the bottom outer wiring plate, and to the engine nose, and similarly to the rudder post. Measurements are also taken from the tail plane extremities to similar points on each side of the fuselage.

The dimensions *b*, *b* should not have a variation of more than $\frac{1}{4}$ in. in 20 ft. The dimensions *a*, *a*, $\frac{1}{4}$ in. in 20 ft. *c*, *c* varies greatly with the size of the tail, but it should approximate in accuracy to *a*, *a*.

Another check is to measure the distance from the centre of the front outer strut to the front bolt on the drag wire wiring plate in front of the fuselage.

Caution.—While the adjustment of the main planes has just been described in stages, it must be noted that in practice the dihedral angle, incidence, and the stagger should be continuously checked, the one against the other, for any alteration to one may alter slightly the adjustment of the others. The method outlined obviates this difficulty as far as possible.

The front drag wires should be connected up when the truing of the main planes is completed.

Tail.—The usual course is to fix, firstly, the fin in position, and secondly, the tail plane. The bracing wires between them are then attached. Next the tail plane spars are trued by aid of a spirit level until they are horizontal, and the fin post adjusted, with a plumb bob, until the rudder hinges are vertically one over the other.

The tail plane is tested for squareness by check measurements from points on the extremities to some fixed point on the fuselage, say the gun pivot on the gunner's platform; also to the main plane struts. The rudder and elevators are then attached, and secured by fitting split pins.

Rigging of Control —
the following is a *general* —

1. Lash rudder bar —
across the fuselage.
2. Lash the pilot's seat —
some other position —
3. Connect up the —
means of the —
rudder is pointing —
of the aeroplane.

4. Adjust the —
turnbuckles, until —

(By this latter —
should be —
is always —

5. Adjust the
ailerons have —

6. Connect
until they are —

7. Connect
elevators are —
(Unless are —

8. If the —
be rigged —

9. If the —
ment —
(Unless —

10. Connect
gear —
control —

11. If —
the —
the —

12. If —
the —
the —

13. If —
the —
the —

14. If —
the —
the —

15. If —
the —
the —

NOTING

for Schools—Fees and Time taken to Fly—
the Ground—Straight Flights—Alighting—
Aviator's Certificate—Training—Flying in a
Rules for Judging Distance—Physiological
violation—Legal.

ING AN AEROPLANE

Agency is *practice*, as in other sports. But if
principles are well understood, the period of
learning, and the preliminary lessons more quickly

best, quickest, and safest method of learning to
organised school. Such an institution offers many
the least of which is its organised tuition, also its
covering any or all damage a pupil may do to
uses or to third parties.

Regulations for Schools

tion of ensuring a definite standard of tuition up
obtaining an Aviator's Certificate, the following
been drawn up by the Royal Aero Club:—

1. A pupil shall have obtained an F.A.I. Aviator's
and have been fifteen hours in the air in control of
obtaining his certificate.

2. The number of pupils for each machine in flying

3. The number of pupils for each instructor shall be

4. A proportion of reserve machines to replace those
be one for every three in use.

5. A pupil shall be in the air in the aggregate
several flights for an Aviator's Certificate shall
at least two hours shall be solo.

6. A register of pupils under instruction,
particulars of all flights made by them,
inspection at any time without notice by
Club appointed for that purpose.

though not always, droop a little, say $\frac{3}{4}$ in. to 1 in., and the aileron control cables should be fairly slack. With the rudder bar square in the fuselage, the controls must be so adjusted that the rudder and the tail skid are in the centre line of, and normal to, the machine.

On completion of the alignment all the turnbuckles must be securely locked, and also inspected to see that they have a full hold on the threads. All bolts and nuts and split pins must be examined, and if necessary the ends of the bolts should be slightly burred over. All cables should be moderately tight. If a wire shows signs of being too taut, it is a certain sign that some adjustment or combination of adjustments is incorrect, so a careful examination should be made to ascertain how it may be slackened without disturbing other parts; also what cables could be slightly tightened to relieve the strain on those that are taut.

Checking of Centre of Gravity.—Before testing a new machine it is essential that the C.G. should be verified, so as to avoid accident. This is done by placing the front wheels on a weighing machine, and supporting the tail on a spring balance. First the main planes are set horizontally, then if l = the distance between the two points of support, W = the weight on the wheels, w = the weight on the spring balance, the distance of the C.G. from the vertical line through the wheels will be :—

$$\frac{w \times l}{W + w}$$

Secondly, the tail is lowered until it almost touches the ground. The spring balance reading w_1 is again noted, and also the angle θ that a plum bob line makes with the original vertical line through the wheels (normal to the chord). Then the perpendicular distance of the C.G. above the wheel centres and at right angles to the chord will be :—

$$l \cot \theta \left(\frac{w_1 - w}{W + w_1 - w} \right).$$

D.E.D.A. (Detachable Data) System. U.S. Patent applied for.
R. B. Chase Matthews. Patents (provisionally protected).

PILOTING

Piloting an Aeroplane—Regulations for Schools—Fees and Time taken to Fly—Learning to Fly—Rolling on the Ground—Straight Flights—Alighting—Turning—Volplanes—Tests for Aviator's Certificate—Training—Flying in a Wind—Cross-Country Flying—Rules for Judging Distance—Physiological Effects of Flying—Rules for Aviation—Legal.

PILOTING AN AEROPLANE

THE only road to proficiency is *practice*, as in other sports. But if certain underlying principles are well understood, the period of learning can be shortened, and the preliminary lessons more quickly turned to advantage.

Nowadays the best, quickest, and safest method of learning to fly is to join a recognised school. Such an institution offers many advantages, not the least of which is its organised tuition, also its fixed inclusive fees covering any or all damage a pupil may do to the machines he uses or to third parties.

Regulations for Schools

With the intention of ensuring a definite standard of tuition up to the point of obtaining an Aviator's Certificate, the following regulations have been drawn up by the Royal Aero Club:—

1. Every instructor shall have obtained an F.A.I. Aviator's Certificate, and shall have been fifteen hours in the air in control of a machine after obtaining his certificate.
2. The maximum number of pupils for each machine in flying condition shall be six.
3. The maximum number of pupils for each instructor shall be eight.
4. The minimum proportion of reserve machines to replace those undergoing repair shall be one for every three in use.
5. The minimum time a pupil shall be in the air in the aggregate before making the necessary flights for an Aviator's Certificate shall be five hours, of which at least two hours shall be solo.
6. All schools shall keep a register of pupils under instruction, and a book giving full particulars of all flights made by them, which shall be open to inspection at any time without notice by officials of the Royal Aero Club appointed for that purpose.

7. The Flying Ground shall be kept clear while a pupil is carrying out the tests for an Aviator's Certificate, and each school shall undertake not to allow any of its pupils to fly while a pupil of another school is carrying out the tests for a Certificate.

8. Particulars of all breakages and repairs to machines shall be kept in a book provided for that purpose, which shall be open to inspection by the officials of the Royal Aero Club.

9. The "Rules of the Air," as set out in the Competition Rules of the Royal Aero Club, shall be observed by all pupils.

10. Machines used for instructional purposes shall be inspected frequently by an instructor during the day's work, and always after a bad landing, and by a competent mechanic each day.

11. All machines shall be inspected at any time without notice by an independent inspector appointed by the Royal Aero Club.

12. Disputes between pupils and schools shall be submitted to arbitration by the Royal Aero Club.

As the foregoing rules protect the interests of the prospective aviator, it is advisable only to patronise those schools which comply with the regulations as set forth.

Fees and Time taken to Fly.—Fees vary, according to the standing and repute of the school, from £50 to £110. They may seem high, but it must be borne in mind that the depreciation of an aeroplane and its engine is very heavy, especially when used by inexperienced persons. A capitation grant of about £70 is made by the Service to a man who has learned to fly independently, thus practically refunding him his tuition fees if he was trained at a flying school.

As regards the time taken in learning to fly, a good indication is given by the rule of the Royal Aero Club, stating that before a pupil presents himself for the Flying Certificate test, he must have been in the air in the aggregate for five hours, of which at least two hours must be solo. As is the case in certain sports, some learn more easily than others, having a more natural aptitude. Weather has an important bearing on flying, and it is best practised by beginners in calm air. The waiting for suitable weather conditions causes very considerable delay, so for this and other reasons it usually takes, at the very least, two months to gain an Aviator's Certificate.

Learning to Fly.—In the best schools the pupil is taken in the first place for passenger flights in order to get accustomed to the sensation of being in the air. The beginner should go up as a passenger for at least three hours in half hour trips before he attempts to control the machine for himself. His first ascents should be made up to a considerable height in a good machine, so that he may early accustom himself to conditions at such heights. He will find it extremely difficult at first to judge of the position of clouds. If he flies high he will also encounter fewer bumps. A bump at any height up to 2,000 ft. will affect the whole aeroplane,

whereas only a part of the machine, such as the tail, is affected at 5,000 ft. This latter partial disturbance gives the impression of the engine missing fire.

As far as rarefaction of the atmosphere at considerable heights is concerned, it is not very noticeable to a man who is fit, even at 10,000 ft.; the engine, however, will run more smoothly. On some school aeroplanes dual control columns are fitted, so that the beginner in the initial stages merely allows his hands to follow the movements of the levers which are guided by the pilot; then gradually he can start controlling the aeroplane himself, any wrong movement being at once corrected, and possible accidents avoided, by the skilled operator who has hold of another lever controlling the same movement. The only objection that might possibly be raised to this method is that when the learner flies by himself he is inclined to lose confidence, being unaccustomed to flying alone.

It is important that the would-be pilot should sit in the correct position in relation to the rudder bar. That is to say, he must not sit with legs rigid, but slightly bent, so that he can push forward firmly from either knee, and feel that he has full control of the rudder bar. Further, in the correct position a toggle action of the knees is possible, and this is imperative in taxiing, which is the next art to be practised. In order to practise rolling the beginner must learn how to use both rudder and switch.

Straight Flights.—When control of the machine while rolling has been learnt, the next stage is making straight flights and subsequent landings with an instructor. Some machines rise more easily into the air than others—especially school machines of modern design with planes having a big camber. An exception has to be made in the case of old type school machines, which have often literally to be dragged into the air. Pupils find “taking off” most troublesome. Most of the trouble, however, arises out of the fact that when the machine gets light on the ground, they draw back the control column too soon, and tend to rise to a height of say 10 or 20 ft., which results in the aeroplane stalling. The aeroplane should be run with the control column and tail set in an automatic position for self-climbing and self-flying. “Taking off” must not be attempted until the aeroplane has got up to the correct speed, which is at the minimum 50 m.p.h., and 80 m.p.h. for actual climbing. If the aeroplane does not “float off” with increase of speed, which is the best method of rising, provided the machine permits of it, the elevator will have to be moved slightly. It must be noted that the chief point in the working of the elevator is the small degree of movement and the lightness of touch required. With regard to the lateral movements, it must be remembered that when an aeroplane turns, it leans over towards the centre of the curve; so that when a plane rises unduly for any reason, it can be corrected by pulling or pushing the control column gently in a lateral direction towards the elevated plane. Another method of

correcting the bump is to pull down the aileron attached to the plane, which is the lower for the time being; either or both of the methods may be used simultaneously. The effect of pulling down the aileron or of warping the plane is to raise the end of the plane, and at the same time to slow it, as more work has to be done to throw downwards a larger quantity of air. Steering towards the raised plane has the opposite effect of accelerating the lower one. The flight at first will naturally be somewhat unsteady, under the guidance of inexperienced hands. However, all deviations from normal flight must be corrected as they occur; it does not do to wait until they are pronounced. After each movement of a lever or wheel the control must be brought back into the normal position.

Though modern aeroplanes have a good deal of inherent stability, it is to be feared that the same cannot be said of school machines, and possibly it is just as well, for it makes the pupil more resourceful.

In order to gain confidence it is always wise to look ahead, and never over the side, as in the latter case the ground seems to be dangerously near.

Landing.—It is said that nearly the whole art of flying lies in landing, and if a man learns to land well, he will be able to do practically anything he likes, provided he has a good nerve.

Landing is accomplished, when near the ground, by moving the elevator to "flatten out" the machine. Previously to this, when quite high up, the pupil should prepare himself by testing his position for horizontal flight and fixing it by some such gauge as the position of his elbow-joint on his side. He must next gently depress the nose of the aeroplane, at the same time throttling right down, and maintain the machine in its natural flying position for gliding. If the aeroplane is properly rigged it will glide "hands off." After this he turns off his engine. When near the ground, as already mentioned, he must "flatten out." During a short distance of horizontal flight he allows his speed to reduce until the undercarriage wheels come lightly in touch with the surface of the earth. After the pupil has proved his confidence in making short straight flights with the instructor, alighting each time before turning, which latter manoeuvre is accomplished on the ground, he is allowed to fly alone until he can handle and land the machine with confidence.

When the pupil is forced to land on rough ground, he should operate the controls as if he were on imaginary ground 3 or 4 ft. above the actual ground, and then pancake down. In order to prevent ruts from swinging the aeroplane, the rudder bar must be held very tightly by the legs.

Once landed it is most important to turn off the ignition switch, for some one may turn the airscrew, when an accident might occur. The petrol, too, must be turned off.

Turning.—When straight flights can be satisfactorily accomplished without the instructor, turning can be attempted with

DE-17A (Detachable Data) System
R. Borlase Matthews' Patents (provisionally protected). U.S. Patent applied for.

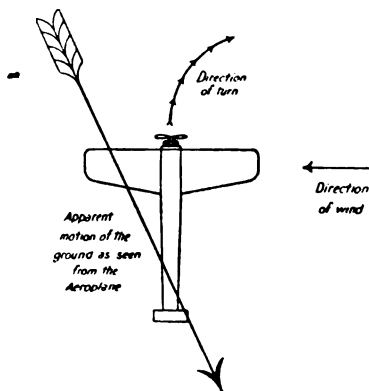
the instructor in the passenger's seat. It is imperative for the beginner not to turn on a climb, or the aeroplane may be stalled, as owing to the increased demand for power the speed is reduced. His turns should be made during the periods of horizontal flight at first, though in the early stages it is better to nose slightly when turning, and if there are any signs of a failing engine the aeroplane must at once be placed in a gliding position. For should the engine stop before this, there would again be the risk of the craft losing speed. If this occurred it would, as previously mentioned, stall, and fall tail first or side-slip, and the aeroplane would then become entirely out of control. The beginner should also bear in mind that at any angle over 45° the elevator acts as a rudder, and vice versa. For turning with a small radius a force must be introduced to counteract the centrifugal force caused by the turn. This is effected by "banking" the aeroplane; on most machines it is to some extent automatic, since the outer ends of the planes are moving faster than the inner, and so exercise a greater lift, and accordingly tend to rise. If the automatic banking is insufficient it must be increased by lowering the aileron on the outside of the curve. It is, of course, possible to calculate the angle at which a machine should turn with the least tendency to "side-slip," but there are quite possibly unknown factors which vitiate the value of the calculation. A table is given herewith for what it may be worth.

THEORETICAL ANGLES OF HEEL FOR VARIOUS SPEEDS AND
RADIi OF TURNS

Radius of Turn in Yards.	Velocity Relative to Wind in Miles per Hour.				
	20	40	60	80	100
	Angles of Heel.				
	Degs.	Degs.	Degs.	Degs.	Degs.
20	24	61	...	...	...
40	12	42	64	...	...
60	8	31	52	67	...
80	6½	24	45	61	...
100	5	20	39	55	66
200	2½	10	22	35½	48
300	1½	7	16	25	36
400	1½	5	11	19½	29

Half circuits should only be attempted at the start, first to the left and then to the right, a landing being made at each half-turn. The next stage is the full circuit. After mastering the right and left hand turns separately they are combined to form eights in the air. In due course follows higher flying and volplanes, which completes the course. Practice then is only required to attain the necessary proficiency and experience to gain the certificate.

After turning across the wind, in a correctly banked turn, when but a few hundred feet up, the ground appears to be moving sideways from the pilot, i.e., as if an over-banked turn had been carried out at a considerable altitude. On the low turn, therefore,



Handling in a Wind.

there is a temptation to hold the lower wing up, and so bring about an under-banked turn.

The quickest way for an experienced pilot to turn about face, is that known as the Immelmann turn. For a turn to the right, the control column is gently but continuously pulled into the right side. At the same time a pull is put on the rudder. When the turn is completed the controls are brought back to the central position. The reverse procedure is followed for a similar left-hand turn.

Volplanes, or descents with the engine stopped from considerable heights, should next be carried out. It will be found that the aeroplane is as well under control as when the engine is operating, only, of course, it is continually gliding towards the ground. Turns to the left or right can be made, and within limits the angle of

glide can be modified. All nose dives should be pulled out very gently.

Flying in a Wind.—As far as the actual management of the aeroplane in the air is concerned, experience is the only teacher. The faster the aeroplane is, the safer it will be in a wind. If the nature of the ground permits, the start should be made with the wind ahead. Once off the ground, if the wind is steady, no serious difficulty will be met with, except, of course, gusts and remous, which are apt to be very disconcerting to the beginner. Care must be taken when a turn through 180° is attempted. Obviously the speed of the aeroplane relative to the air must be maintained, and in a turn from up wind to down wind this means increasing the speed of the aeroplane relative to the ground by an amount double the velocity of the wind. The usual method is to rise just before making the turn, and swoop downwards as the turn is made. When alighting the aeroplane must again be brought head to wind. To do this, the apparent motion of the ground, which will be at an angle to the course of the aeroplane, must be noted, and the machine turned *away* from the direction of this motion, i.e., in the figure the turn must be made as shown by the arrow. Failure to come down head on to the wind may mean an awkward spill, and probable damage to the aeroplane.

In gusty winds the pupil must keep clear of sheds, or trees, or rises in the ground, as these cause vertical air currents and bumps which may catch the tail and force a nose dive. In gusty weather the speed of landing should be as high as the ground permits within the limits of the skill of the pupil.

Cross-Country Flying.—When the pupil has practised straight flights, turns, volplanes, and landings within prescribed limits from any height, and over obstacles, until he is positively weary, then and then only is he allowed to begin cross-country flying. The first cross-country flight is to every true-born aviator one of the great moments in his career. He must always maintain a good height, at least 3,000 ft., and preferably not less than 6,000 ft., especially across strange country, to give him time to pick and choose safe landing places.

On first rising into the air the pupil should make note of two prominent objects in the distance, so that in steering on the set course by compass he may make correction for sideways drift.

Reference for fuller details and hints should be made to such books as "Flying," "Learning to Fly," and "The Flying Guide," which are reviewed in Division 629.13.016.

Engine Trouble.—If engine trouble arises the aviator should reduce his revolutions to a number sufficient to just keep his machine flying. It is assumed that he is up at a good height, and he must not attempt to climb any higher. He should rather endeavour to make for the nearest aerodrome, and at the same

time keep a good look-out for large fields, preferably not ploughed, on which to effect as speedy a landing as possible. If the engine gets more erratic, and there is any suspicion of back-firing, he must put his aeroplane into a position for a glide, switch off the engine altogether, and then volplane down, preferably in a spiral, to the nearest large field. He should remember that it is less risky to charge a hedge at 20 miles an hour than to stall at 20 ft.

It should be impressed on beginners that in the event of the engine failing, or showing signs of failure after having taken off, the aviator's only safe course is to put the nose of the aeroplane down, that is, dive her at the natural gliding angle in the same line of flight, and go straight on. Many fatal accidents are caused through pilots trying to turn back into the aerodrome when the engine has cut out, or through keeping the machine in a climbing position which will result in a stall. Every would-be flyer should understand the serious consequences of trying to turn with the engine off. It would be safer for him to crash into a house when going forward than to side-slip or stall an aeroplane with engine trouble.

Adjustable Tail.—Many aeroplanes have what is known as an adjustable tail. This enables the aviator to alter the trimming speed during flight, by adjusting the angle of the tail by means of a hand-wheel on his right-hand side. The trimming speed is slower when gliding with the engine off than flying with the engine on, but this may be corrected in a similar way. The adjustable tail also gives the pilot the advantage of carrying a varying load in the back seat. Many two-seater aeroplanes cannot be flown without either a passenger or an equivalent weight of ballast.

Cautions by the Way.—Pupils should always fly high. They should keep out of the backwash of other craft, particularly when near the ground. Stunting should not be carried out too near the ground, as people near by may be seriously injured, and incidentally the aeroplane is of value and often gets damaged by careless handling in this way. For the same reason fast taxiing and sharp turns at any speed should be avoided.

It is better and also a time-saver to use a two-wheel carriage with a turn-table top fitting under the tail skid, for handling an aeroplane on the ground, rather than lifting the tail by hand. The mechanics should be cautioned not to press on the elevator cables when the tail is carried.

Observers or passengers should always use safety belts, as the pilot may start stunting without warning. Never release the belt while in the air, or when nosed down to land. It must only be released when the machine is on the ground and travelling at not more than 20 m.p.h., when, in case of fire, the belt should be loosened in order to get free as quickly as possible after landing.

Always remember that altimeter must be corrected before starting.

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- (a) Climb out of a field 2,000 ft. square, and attain 500 ft. altitude, keeping all parts of the machine inside of square during climb.
- (b) Glides at normal angle, with motor throttled. Spirals to right and left. Change of direction in gliding.
- (c) At 1,000 ft. cut off motor and land within 200 ft. of a previously designated point.
- (d) Land over an assumed obstacle 10 ft. high, and come to rest within 1,500 ft. from same.
- (e) Cross-country triangular flight of 30 miles, passing over two previously designated points. Minimum altitude, 2,500 ft.
- (f) Straightaway cross-country flight of 30 miles, landing to be made at designated destination. Both outward and return flight at minimum altitude of 2,500 ft.
- (g) Fly for forty-five minutes at an altitude of 4,000 ft.

Training.—A good deal of knowledge and experience still remains to be acquired after the Aviator's Certificate has been awarded. Among the important matters to be practised are:—

Estimations of necessary length of run over various kinds of ground.

Estimations of horizontal distances and vertical heights.

Flying in winds.

Reading of maps and learning to recognise the nature of objects as seen from above. Especially map reading in relation to the compass.

Navigation of an aircraft by aid of map, compass, etc.

Observations of natural conditions affecting weather and their influence on flight.

Modifications of wind due to obstacles on the earth's surface.

629.13.52.0045

Inspection after Flight.—The symmetry of the leading edges of the main planes about the centre line of the machine must first be verified. The centre section bracing wires should then be tested for tautness, and the locking devices examined.

The dihedral incidence and stagger should be checked, and it must be seen that the interplane struts are true.

All the main plane bracing wires should be inspected for tautness and length, and the locking arrangements looked into.

The tail plane actuating gear, all controls, control pulleys, and cables, particularly the compensating cable, should be looked over to see that they operate freely, and that there are no signs of wear or rust on the cables. Also see that all splices are sound. The tail plane, rudder, and fin should be tried to ascertain if they are correctly set and square with the machine, and that all bracing wires are taut.

The droop of the ailerons and the setting of the elevators should also be measured, and the undercarriage, not omitting the split pins securing the wheels to the axle, main plane skids, and tail skid examined.

Attention should next be paid to the tank supports, fittings, and connections, special search being made for any possible leaks, by noticing the condition of surrounding parts of the fuselage.

The engine mounting, controls, and accessories next need careful inspection. If the machine is fitted with guns, the gun chutes should be examined to see that they line up with the feed block of the gun. Also the sights for alignment, and the security bolts for tightness, must be tested.

DE-DA (Detachable Data) System
R. Borlase Matthews Patents (provisionally protected) U.S. Patents applied for.

CORRECTIONS OF FAULTS IN FLYING**1. List.**

An aeroplane will fly with a list to one side when there is—

- (a) Insufficient incidence on the main plane on that side.
- (b) Too much incidence on the main plane on the opposite side.
- (c) Airscrew torque.
- (d) Slack fabric on the main plane that is depressed.

2. Nose Heavy.

An aeroplane will fly nose heavy when there is—

- (a) Insufficient incidence on the main plane.
- (b) Too much incidence on the tail plane.
- (c) Insufficient stagger (this has less effect than the previous two items).

3. Tail Heavy.

An aeroplane will fly tail heavy when there is—

- (a) Too much incidence on the main plane.
- (b) Insufficient incidence on the tail plane.
- (c) Too much stagger (this has less effect than the preceding items).

4. Tendency to Turn.

An aeroplane will tend to turn constantly in one direction, if the effect of the airscrew slip stream on the fin and the rudder is uncorrected.

UNDERCARRIAGE WHEELS

(Palmer)

Tyre Sizes.	Wheel No.	Hub.		Track Line. m./m.	Tyre Sizes.	Wheel No.	Hub.		Track Line. m./m.
		Length.	Bore.				Length.	Bore.	
300 × 60	16	m./m. 111.12	m./m. 25.4	Cent.	750 × 125	92	m./m. 185	m./m. 55	135.50
"	17	72.39	12.7	Cent.	"	95	185	55	Cent.
450 × 60	30	89	31.75	Cent.	"	77	178	44.45	132/46
575 × 60	111	150	38.09	104/46	"	33	150	38.09	Cent.
"	21	160	28	Cent.	"	99	178	38.89	132/46
"	34	150	31.75	104/46	"	96	178	55	132/46
650 × 65	78	178	44.45	132/46	"	112	150	40	Cent.
"	79	178	44.45	Cent.	800 × 150	82	185	55	135/50
"	100	178	38.09	132/46	"	85	185	55	Cent.
"	101	178	31.75	132/46	"	+36	185	55	135/50
600 × 75	111	150	38.09	104/46	"	+40	185	60.32	135.50
"	21	160	28	Cent.	"	+41	185	55	Cent.
"	34	150	31.75	104/46	"	106	185	47.62	135.50
700 × 75	78	178	44.45	132/46	"	+205	185	60.32	Cent.
"	79	178	44.45	Cent.	900 × 200	202	185	60.32	Cent.
"	100	178	38.09	132/46	"	107	185	55	Cent.
"	101	178	31.75	132/46	"	108	185	55	Cent.
700 × 100	92	185	55	135.50	"	120	185	55	125/60
"	95	185	55	Cent.	"	202	185	60.32	Cent.
"	96	178	55	132/46	1000 × 150	97	250	65.4	Cent.
"	77	178	44.45	132/46	"	102	285	55	125/60
"	33	150	38.09	Cent.	"	201	185	60.32	125.60
"	99	178	38.89	132/46	1100 × 200	52	185	55	116/69
"	96	178	55	132/46	"	57	185	55	Cent.
"	112	150	40	Cent.	"	203	185	60.32	116/69
					"	204	185	60.32	Cent.

The sizes in most general use are those with the Nos. in heavy type.

Wheel No. 21 weighs 9 lbs. 13 oz. and Wheels Nos. 33 and 96 weigh 21 lbs. 3 oz.

† Wheels Nos. 36, 40, 41, and 205 are of stronger type than the other wheels for 800 × 150 tyres.

Pat. D. 4 (Detachable Disc) System
R. H. & Co. Patents (periodically protected) U.S. Patent applied for.

TYPICAL AIRCRAFT

Diagrams of Airco DH4, Airco DH5, Airco DH6, Airco DH10A, Avro, Bristol, Albatros, F.B.A. Flying Boat, F.E. 2B, Gotha, Handley-Page, RE8, SE5A, Short S184, Sopwith Camel, Sopwith Torpedo Aeroplanes—U.S. Navy Dirigible—French, British, and German Airships—British Aeroplane Data—French Aeroplane Data—Italian Aeroplane Data—German Aeroplane Data—American Aeroplane Data.

On the following pages is given a selection of typical aircraft. The advance in aeroplane design has been remarkable, and machines are improved every month. However, it will be noted that some of the examples are from the designs of firms who are amongst the foremost in initiative and successful design. An example is given of several recent German designs.

Primarily a monoplane only differs from a biplane in the distribution and arrangement of the supporting surface. Machines can be built for the same maximum speeds, whether fitted with one, two, or three planes. But the biplane type, with its box-girder construction, is a simpler solution of the problem of adequately supporting the necessary lifting surface than is the monoplane. Hence, the majority of aeroplanes nowadays are biplanes; but it is quite possible that the recent tendency towards the elimination of wire bracing may culminate in the standardisation of the monoplane type for high-speed work. It is likely that the aeroplane of to-morrow will be constructed of metal, which will simplify the problem of obtaining rigidity without the use of the box-girder system, and so bring the monoplane and biplane more or less on the same footing from this point of view.

The total number of types of aeroplane now in existence is very large. The reader who desires a concise and practical guide to the recognition of different types and makes of aeroplanes and airships is referred to "The Aircraft Identification Book," by R. Borlase Matthews and G. T. Clarkson. Publishers: Crosby Lockwood & Son. Price, 3s. 6d. (See notice in the Bibliographical Division.) An explanation is given in this book of the reference numbers printed to the right of the title of each diagram.

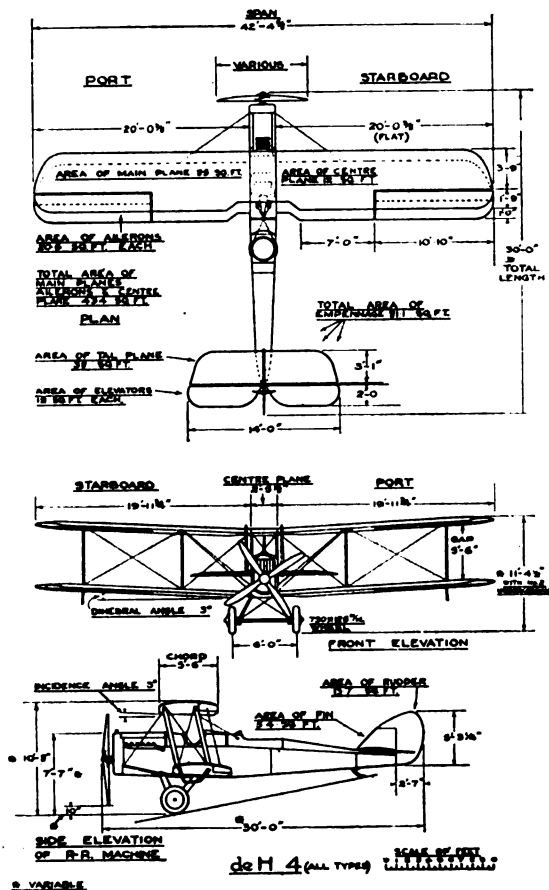
The initial letter of these reference numbers indicates whether the diagram illustrates an aeroplane (P), a float-type seaplane (S), or a flying boat (B).

The first figure indicates the number of planes.

The second figure indicates the number of airscrews, and whether tractor or pusher.

The fifth figure indicates the number of interplane struts.

The sixth and seventh figures indicate stagger, dihedral, and type of engine.



Airco DH4

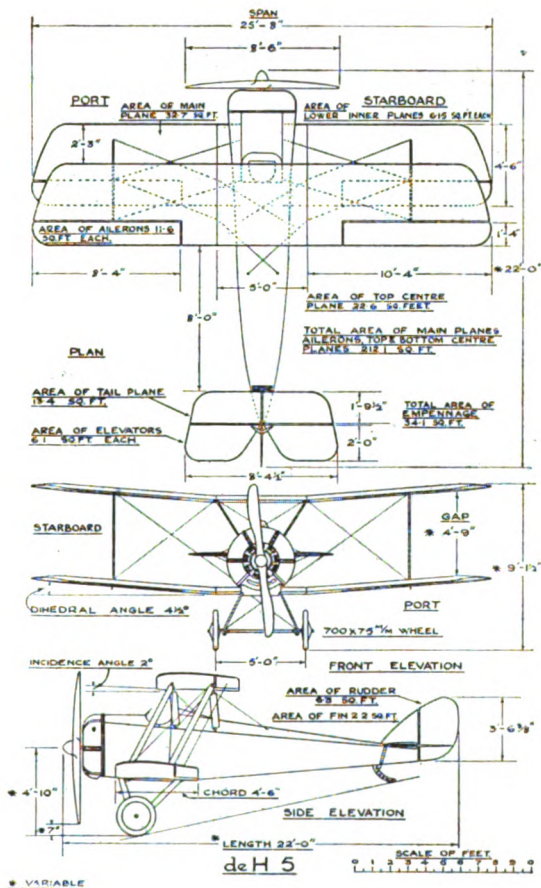
P 21.035.24

A two-seater tractor biplane. Span, 42 ft. 4 1/2 in. Chord, 5 ft. 6 in. Gap, 5 ft. 6 in. Length, 30 ft. Height, 11 ft. 4 1/2 in. Area of planes, 434 sq. ft. Weight, 2,950 lbs. 375 h.p. Eagle Rolls-Royce engine.

TYPICAL AIRCRAFT

629.13.52

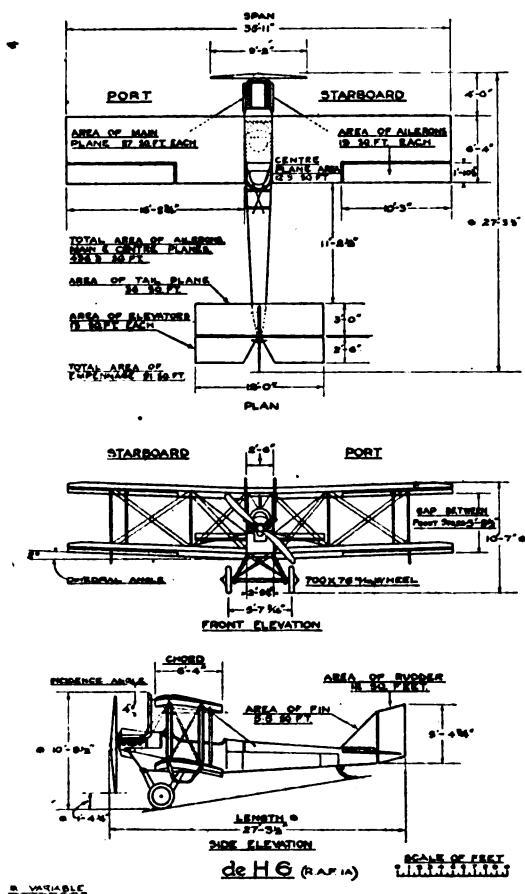
Crosby Lockwood & Son's TECHNICAL DATA SERIES.



Airco DH5

P 21.034.81

Single-seater tractor scout. Span, 25 ft. 8 in. Chord, 4 ft. 6 in. Gap, 4 ft. 9 in. Length, 22 ft. Height, 9 ft. 1 1/2 in. Area of planes, 212 sq. ft. Weight, 1,080 lbs. 110 h.p. Le Rhone rotary engine.



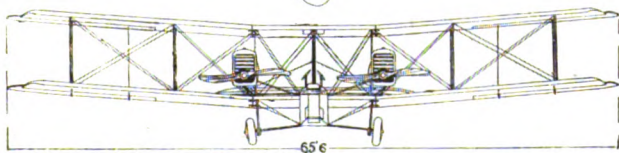
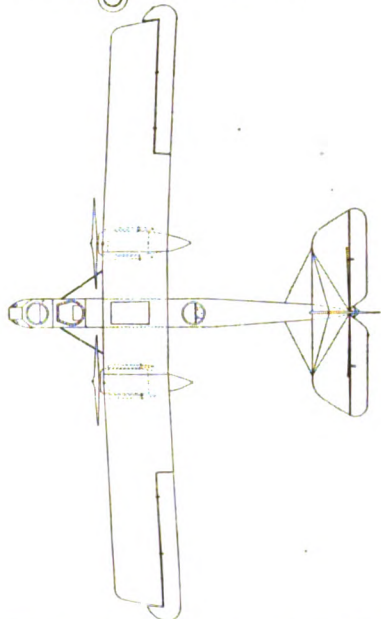
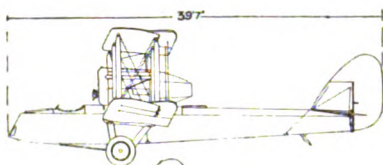
Airco DH6

P 21.035.84

Two-seater tractor school machine. Span, 35 ft. 11 in. Chord, 6 ft. 4 in. Gap, 5 ft. 8 1/2 in. Length, 27 ft. 3 1/2 in. Area of planes, 436 sq. ft. Weight, 2,750 lbs. 90 h.p. engine.

TYPICAL AIRCRAFT

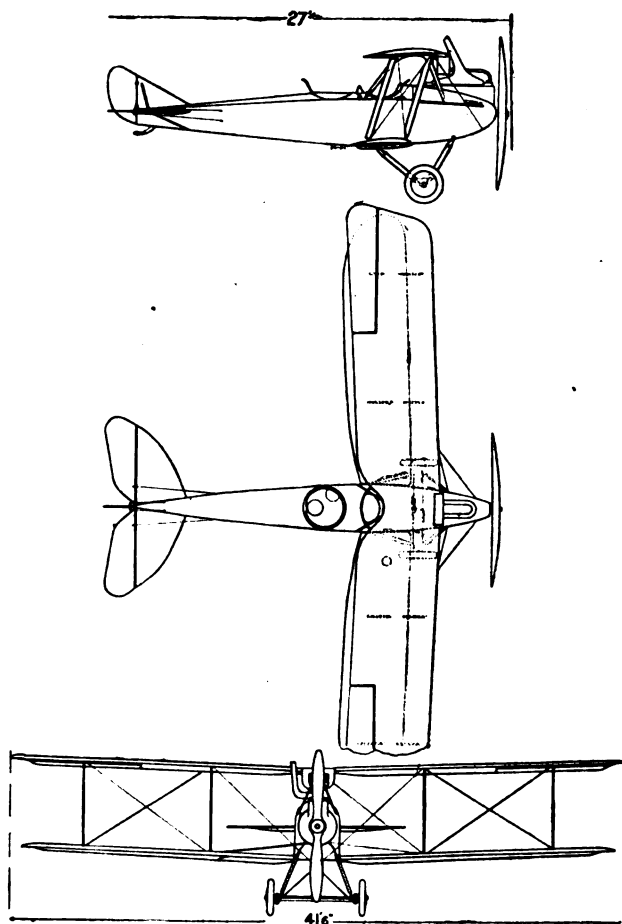
629.13.52



Airco DH10A

P 22.035.54

A day bomber, three-seater, twin engine biplane. Span, 65 ft. 6 in. Length, 39 ft. 7 in. Area of main planes, 851 sq. ft. Gross weight, 8,750 lbs. Two 405 h.p. Liberty or Rolls-Royce engines.



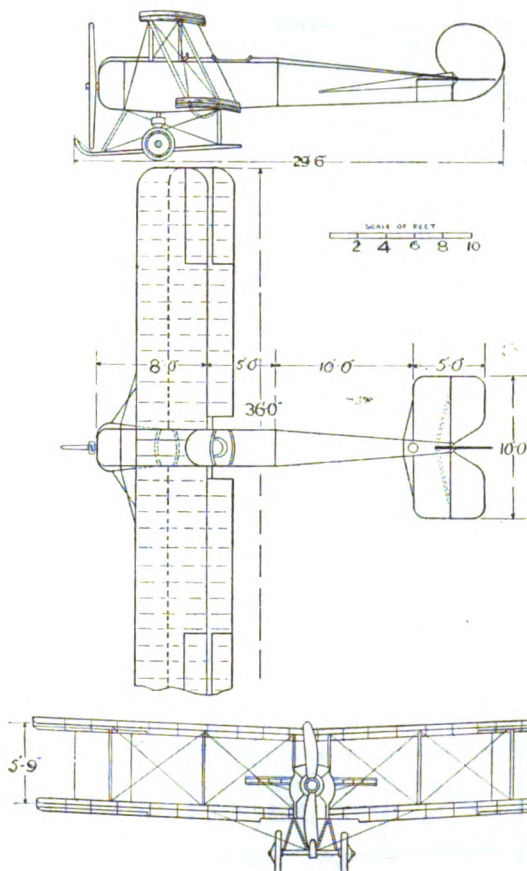
Albatros (CIII)

P 21.035.23

Two-seater tractor biplane. Span, 41 ft. 6 in. Chord, 6 ft. 1 in.
 Length, 27 ft. Gap, 6 ft. 4 in. Area of main planes, 446 sq. ft.
 Weight, 1,863 lbs. Load, 968 lbs. 260 h.p. Mercedes engine.

TYPICAL AIRCRAFT

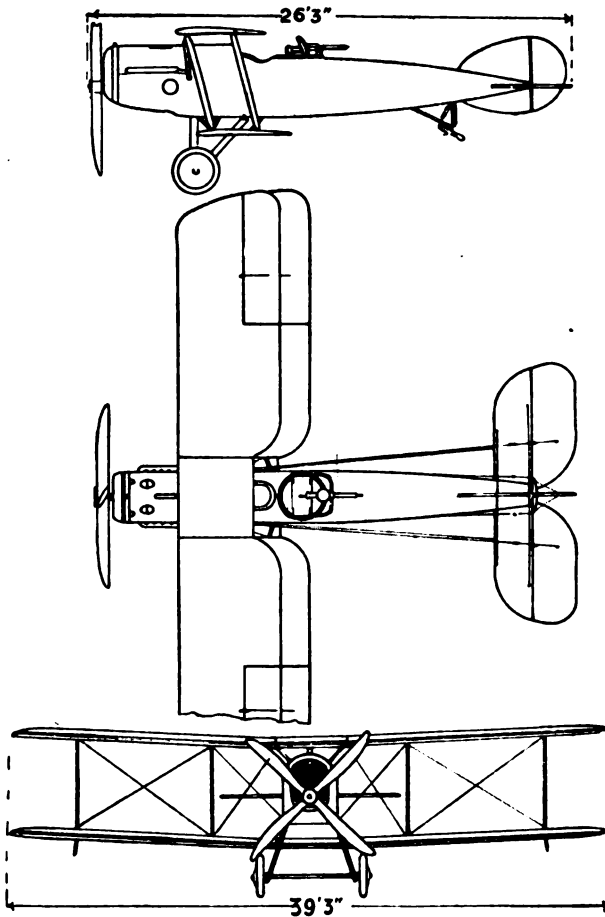
629.13.52



Avro Biplane

P 21.035.21

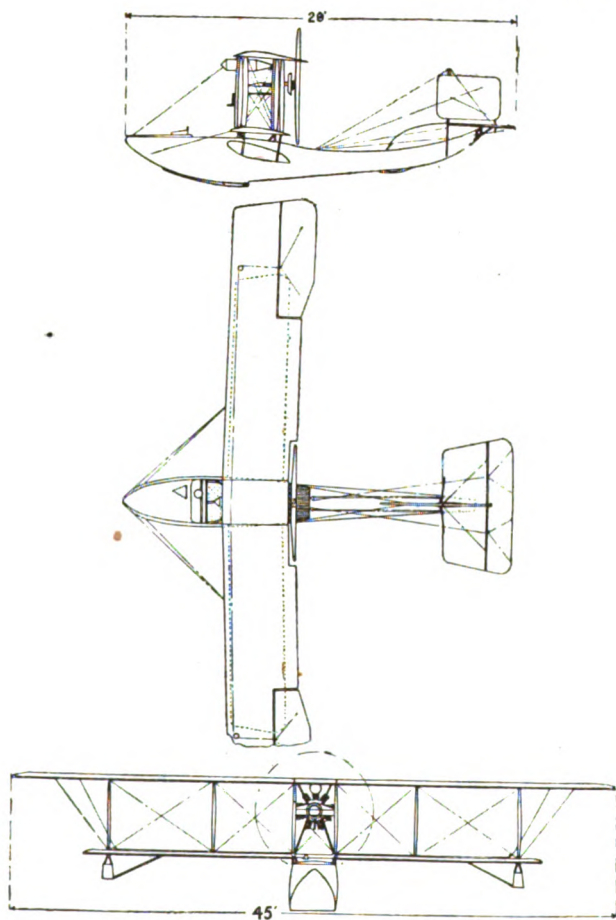
A tractor two-seater biplane with staggered planes and mono-plane tail. Chord, 4 ft. 9 $\frac{3}{4}$ in. Area of main planes, 342 sq. ft. Area of tail, 46 sq. ft. Loading of main planes, 5 lbs. per sq. ft. Weight, light, 1,050 lbs.; with pilot, passenger and 4 $\frac{1}{2}$ hours' fuel, 1,700 lbs. Engine, 80-100 h.p. rotary. Speed, 78-83 m.p.h. Climb, 350-400 ft. per min. Makers: A. V. Roe & Co., Ltd., Manchester.

**Bristol Fighter****P 21.035.24**

Two-seater tractor biplane. Span, 39 ft. 3 in. Length, 25 ft. 10 in.
 Area of main planes, 406 sq. ft. Gross weight, 2,848 lbs. 275 h.p.
 Falcon III. Rolls-Royce engine.

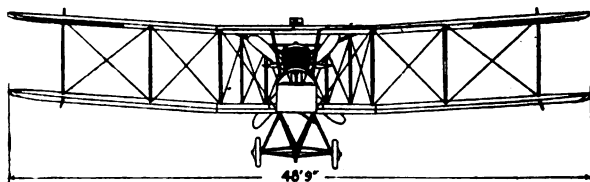
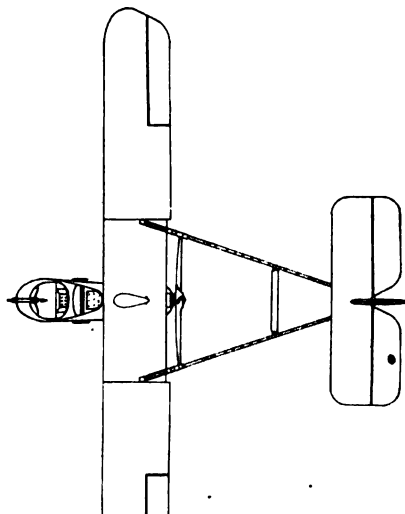
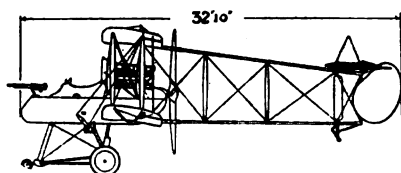
TYPICAL AIRCRAFT

629.13.52



F.B.A. Flying Boat

Two-seater pusher flying boat. Span, 45 ft. Length, 28 ft. Height, 17 ft. 5 in. Total surface, 358 sq. ft. 100 h.p. Mono Gnome engine.



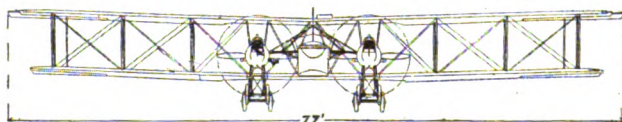
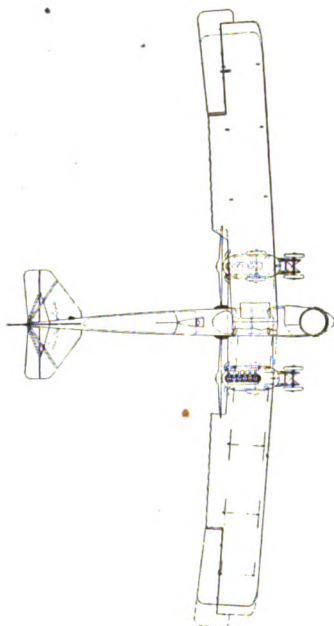
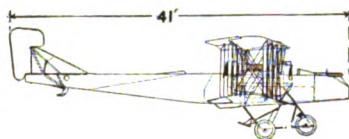
F.E. 2B

P 24.036.53

A night bomber, two-seater pusher. Span, 47 ft. 9 in. Chord, 5 ft. 6 in. Length, 32 ft. 3 in. Gap, 6 ft. 3½ in. Height, 11 ft. 9 in. Area of main planes, 494 sq. ft. Gross weight, 3,037 lbs. 160 h.p. Beardmore engine. Designed by R.A.E.

TYPICAL AIRCRAFT

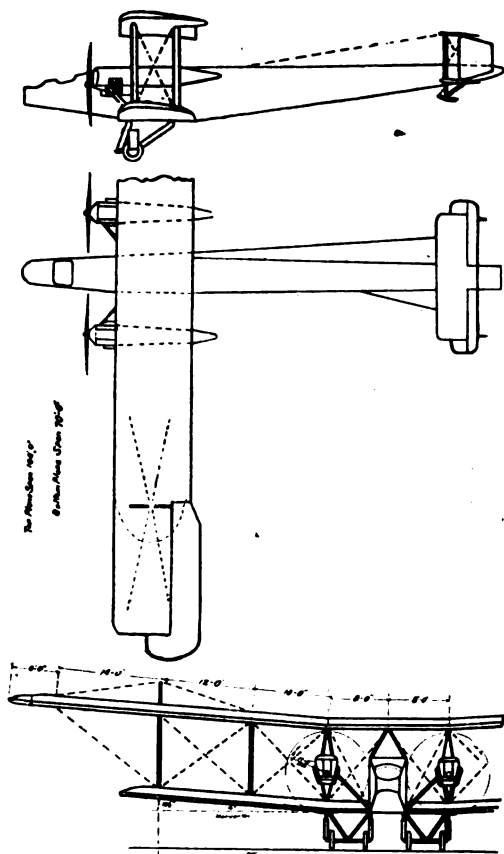
629.13.52



Gotha

P 25.036.53

Span, top plane, 77 ft.; bottom, 70 ft. 6 in. Chord, 7 ft. 2½ in. Length, 41 ft. Gap, at fuselage, 8 ft. 6 in.; at plane tips, 7 ft. 2 in. Height, 12 ft. 8 in. Weight, 4 tons, with 1,000 lbs. of bombs and 1,320 lbs. of petrol and fuel. Speed, 72 m.p.h at 12,000 ft. Area of main planes, 985 sq. ft.; of ailerons, 117 sq. ft. Tail plane, and elevators, 61.5 sq. ft. Main plane loading, 8.9 lbs. per sq. ft.; and weight, 16.3 lbs. per h.p. Two 200 h.p. Mercedes engines.



Handley-Page 0.400

P 22.036.54

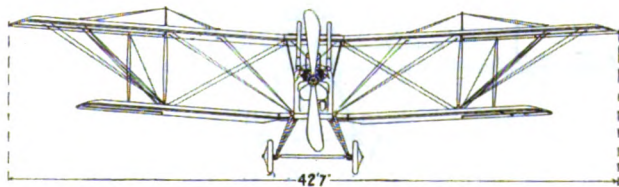
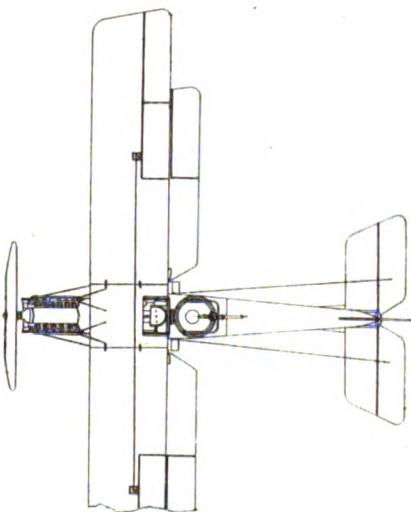
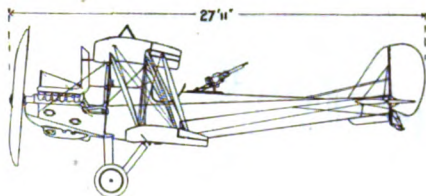
A night bomber.
men. Span, 100 ft.
planes, 1,642 sq. ft.
Speed, 84-90 m.p.h.

This machine has carried a crew of twenty-one
Length, 63 ft. Height, 22 ft. Area of main
Engines, two 275 h.p. 12-cylinder Rolls-Royce.
Gross weight, 12,230 lbs.

*DE.D.A. (Detachable Data) System.
R. Borlase Matthews' Patents (provisionally protected). U.S. Patents applied for.*

TYPICAL AIRCRAFT

629.13.52

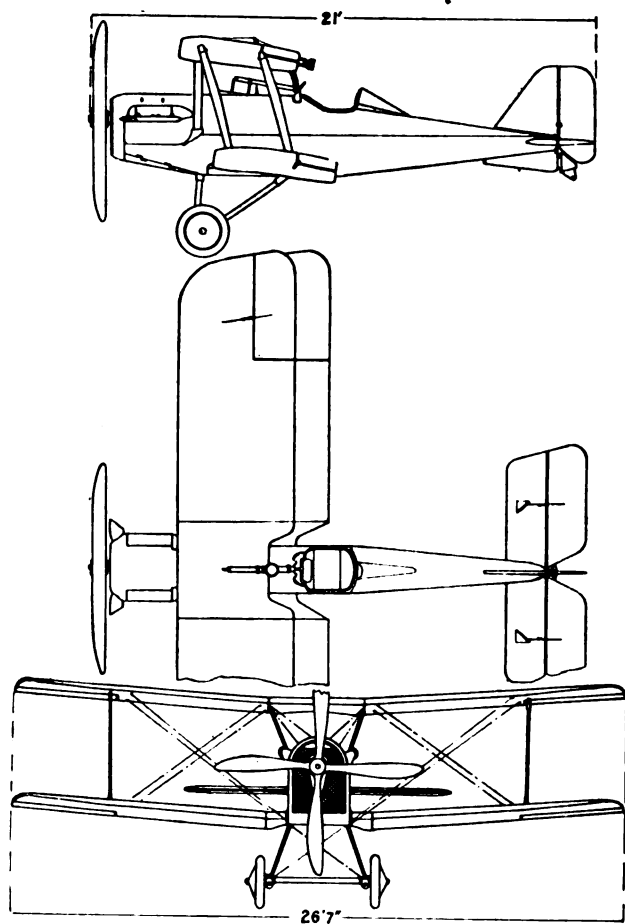


RE8

P 21.034.24

A corps reconnaissance two-seater biplane. Span, 42 ft. 7 in. Length, 27 ft. 11 in. Area of main planes, 378 sq. ft. Gross weight, 2,604 lbs. 150 h.p. R.A.F. 4A engine. Designed by R.A.E.

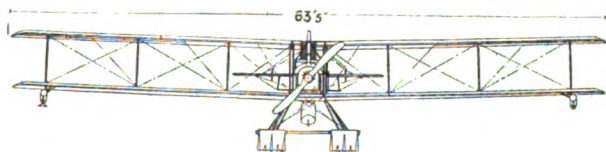
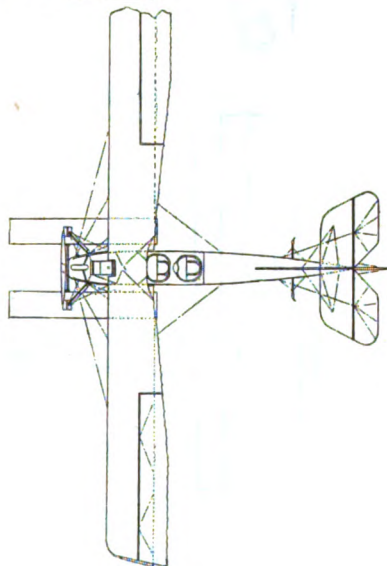
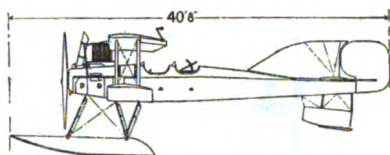
45

**SE5A****P 21.034.24**

A single-seater fighter scout biplane. Span, 26 ft. 7 in. Length, 21 ft. Area of main planes, 247 sq. ft. Gross weight, 1,953 lbs. 200 h.p. Hispano-Suiza engine.

TYPICAL AIRCRAFT

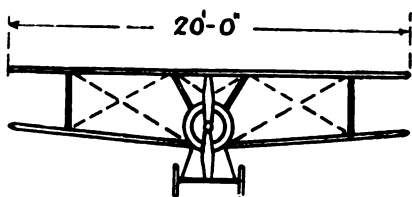
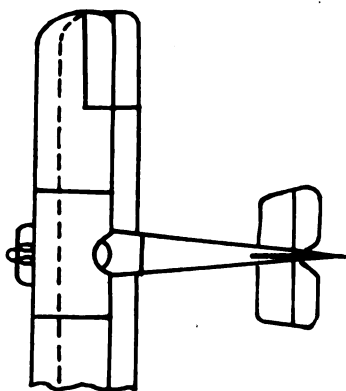
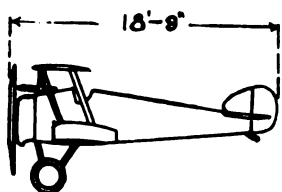
629.13.52



Short Seaplane S184

F 21.035.54

A float type, two-seater seaplane. Span, 63 ft. 5 in. Length, 40 ft. 6 in. Area of main planes, 680 sq. ft. Gross weight, 5,123 lbs. 260 h.p. Sunbeam engine.



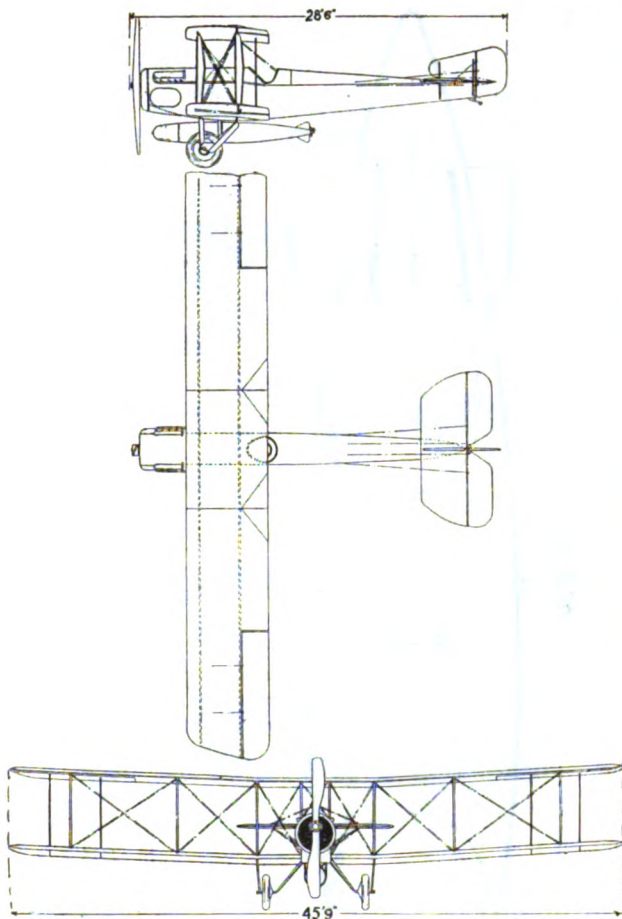
Sopwith Camel

P 21.034.31

A single-seater fighter. Type, F1. Span, 28 ft. Chord, 4 ft. 6 in. Length, 18 ft. 9 in. Height, 8 ft. 6 in. Stagger, 1 ft. 6 in. Area of main planes, 231 sq. ft. Gross weight, 1,450 lbs. 130 h.p. Clerget or 150 B.R.1 engines.

TYPICAL AIRCRAFT

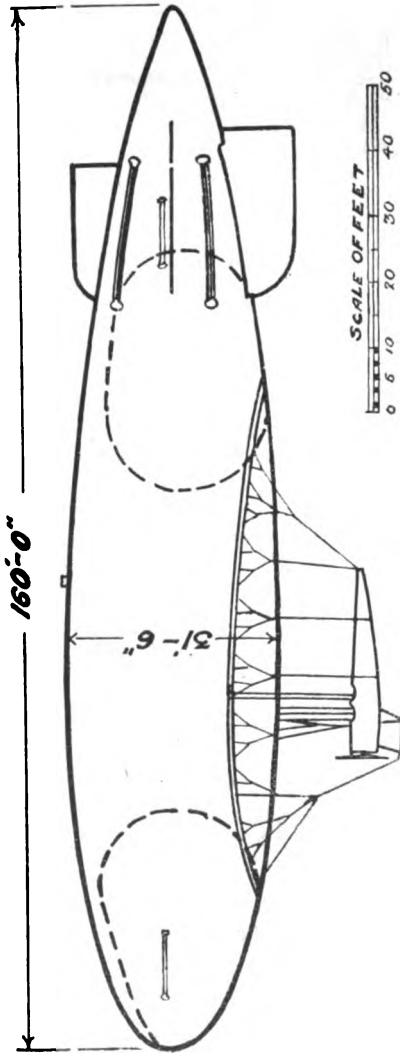
629.13.52



Sopwith Torpedo

P 21.036.54

A torpedo-carrying aeroplane. Span, 45 ft. 9 in. Length, 28 ft. 6 in. Height, 11 ft. Chord, 6 ft. 3 in. Gap, 6 ft. Gross weight, 3,883 lbs. 220 h.p. Sunbeam Arab engine. Total area, 566 sq. ft.



The United States Navy Dirigible

Length, 160 ft. Width, 36-2 ft. Height, 50 ft. Displacement, 77,000 cub. ft. Gross lift, 5,275 lbs. Speed, 45 m.p.h., with range of 10 hrs. Weight, 3,334 lbs. Useful load, 1,941 lbs. 100 h. p. engine.

FRENCH AIRSHIPS

The accompanying silhouettes give an idea of the shape and size of the more important lighter-than-air craft. All the airships illustrated are in use at the present time, or are of sufficient historical importance to warrant a place in these pages. The sketches are all to the same scale, and a vessel which reached from side to side of the page would be 720 ft. long.



ASTRA



CHALAIS



CLEMENT-BAYARD



LEBAUDY



ZODIAC

SPIESS

AIRSHIPS IN BRITISH SERVICE

The **FORLANINI** is a successful Italian design.



ASTRA TORRES

**PARSEVAL**

6. (OR BLIMP) - 1915 TYPE

FORLANINI

TYPICAL AIRCRAFT

629.13.55

The other airships — the **S.S. (or BLIMP)**, **COASTAL PATROL**, and **BRITISH RIGID**—represent developments due



S.S. - LATER TYPE



COASTAL PATROL



BRITISH RIGID

to British initiative since the outbreak of war, and all, particularly the **S.S.** and **C.P.** types, which are non-rigid, have done enormously useful work.

GERMAN RIGID AIRSHIPS

Three German rigid airships are illustrated, viz., a pre-war **ZEPPELIN** with box tail, multiple rudders and elevators; a **SUPER-ZEPPELIN** of the latest type; and a **SCHUTTE-LANZ**.



1912-TYPE ZEPPELIN



1917-TYPE ZEPPELIN



SCHUTTE-LANZ

The **SUPER-ZEPPELIN** has a streamline body and cruciform tail, with monoplane rudders and elevators. This craft is really a composite Schutte-Lanz and Zeppelin, incorporating Schutte-Lanz aerodynamic design with Zeppelin internal construction. The Schutte-Lanz had a framework of wire-braced wood struts, while the Zeppelin, of course, has a lattice-girder frame of channel section aluminium alloy, and is without wire bracing.

Some more detailed notes concerning these airships are given below.

ZEPPELIN AIRSHIPS

A type of rigid airship constructed with aluminium alloy lattice framework.

I.—1900-1914 Type

This airship has a long parallel body with bluff bow and stern. It is provided with an external keel gangway. It has two cars. The rudders and elevators are of the box type. A number of sizes have been constructed with base varying in length from 420 to 500 ft., and a capacity of 400,000 to 800,000 cubic ft. The total horse-power varied from 32 in the 1900 model to 540 in the later ones. The speed of the 1900 model was 17 miles per hour, whereas the later ones attained 47 miles per hour. Two two-blade and two four-blade wing airscrews were fitted to the later models.

II.—1913 L.2 Type

This airship has a long parallel body with a bluff bow, the stern is slightly streamlined, with external keel gangway and three nacelles. It is fitted with four four-blade airscrews. The rudders and elevators are of the box type. The overall length is 525 ft., and the capacity is 920,000 cubic ft. The H.P. of the engines totals 8,000, and the speed is 50 miles per hour.

III.—1915 Type

This also has a parallel body not quite so long in proportion as Types I. and II. The bow is bluff and the stern is streamlined. It has an external keel gangway and three nacelles. The two front ones of each are connected together. Two pusher airscrews are incorporated in accordance with the Schutte-Lanz practice. There are also two wing airscrews. The rudders and elevators are of the balanced monoplane type. The overall length is 525 ft., and the capacity 1,060,000 cubic ft. There are four engines totalling 780 H.P. The speed is 50 to 55 miles per hour.

IV.—1916 L.30 Type

This is the so-called Super-Zeppelin. The general construction of the girders is very considerably altered from that of the previous types,

and many of the features of the Schutte-Lanz are incorporated. There are five nacelles (two forward and combined), one aft and two amidships and abreast. It has a short parallel body, a long rounded bow, and a long streamlined stern. Balanced monoplane rudders and elevators are employed. There are six motors totalling 1,140 H.P., driving six two-blade airscrews; two of each are of tractor wing type, and four of the pusher type. The overall length is 640 ft.; capacity, 2,000,000 cub. ft.; speed, 60 miles per hour.

SCHUTTE-LANZ AIRSHIPS

These are rigid airships constructed with a wood lattice framework which is braced with wire.

S.L.1 Type

This has a characteristically cigar-shaped body. It has two nacelles which are provided with exposed light lattice girder undercarriages. The elevators and rudders are of the monoplane form. Two 250 H.P. Daimler engines (total 500 H.P.) drive two 3-blade airscrews. The overall length is about 425 ft., and the capacity 706,000 cubic ft. Speed, 40 miles per hour.

S.L.2 Type

The cross section of this airship is polygonal. The body is parallel for a considerable length, terminating at the forward end with a blunt nose, and streamlined for a considerable distance towards the stern. It is equipped with four cars, and has monoplane elevators and rudders. The 1914 model is approximately 470 ft. in length, with a capacity of 810,000 cubic ft. Four Maybach 180 H.P. engines (total 720 H.P.). Speed, 50 miles per hour. The 1915 model is approximately 540 ft. in overall length, with a capacity of 1,060,000 cubic ft. It is fitted with four 240 H.P. engines (960 H.P.). Speed, 50 miles per hour.

S.L.3 Type

This is similar in all respects to S.L.2 except that the two forward nacelles are united. The length is increased to 600 ft., and the capacity to 1,275,000 cubic ft., four 240 H.P. Maybach engines (total 960 H.P.) are fitted instead of Daimler, and the speed is 55 miles per hour.

BRITISH AEROPLANES

AEROPLANE.							
No.	Make.	Type.	No. of Crew.	Dimensions.			
				Span. Ft. M.	Length. Ft. M.	Height. Ft. M.	Surface. Sq. Ft. Sq. M.
1	Armstrong-Whitworth	Corps Recon. & Training	2	43·3 13·2	31·4 9·55	11·6 3·6	504 46·8
2	Bristol Fighter	Fighter Recon.	2	39·3 12·0	25·8 7·9	9·8 3·0	406 37·7
3	" "	Corps Recon.	2	39·3 12·0	24·8 7·55	9·4 2·85	405 37·6
4	" "	Corps Recon.	2	39·5 12·05	26·0 7·95	9·4 2·85	406 37·7
5	De Havilland 4	Fighter	2	42·5 12·95	30·7 9·35	10·4 3·2	436 40·5
6	" "	4 Fighter	2	42·5 12·95	29·7 9·05	11·1 3·4	438 40·7
7	" "	9 Day Bomber	2	42·5 12·95	30·5 9·3	10·0 3·05	442 41·1
8	" "	9 Day Bomber	2	42·5 12·95	30·5 9·3	10·0 3·05	442 41·1
9	" "	9A Day Bomber	2	46·0 14·0	30·0 9·15	11·3 3·45	493 45·8
10	" "	9A Day Bomber	2	46·0 14·0	30·0 9·15	11·3 3·45	493 45·8
11	" "	9A Day Bomber	2	45·9 14·0	30·0 9·15	10·8 3·3	488 45·4
12	" "	9A Day Bomber	2	45·9 14·0	30·0 9·15	10·8 3·3	488 45·4
13	" "	10A Day Bomber	3	65·0 19·8	39·8 12·1	14·9 4·55	851 79·1
14	" "	10A Day Bomber	3	65·0 19·8	39·8 12·1	14·9 4·55	851 79·1
15	F.E. 2B	Night Bomber	2	47·8 14·6	32·3 9·85	12·7 3·9	494 45·9
16	Handley-Page 0·400	Night Bomber	4	100 30·5	63 19·2	22 0·7	1,642 152·6
17	Handley-Page 0·400	Night Bomber	3	100·3 30·6	63 19·2	18·5 5·65	1,645 152·9
18	Martinsyde F3	Fighter	1	32·8 10·0	25·5 7·8	8·0 2·45	338 31·4
19	" F4	Fighter	1	32·8 10·0	25·3 7·7	8·0 2·45	330 30·7

BRITISH AEROPLANES—*Continued*

No.	Type.	ENGINE.					
		Normal.		Weight.		Loading.	
		B.H.P.	R.P.M.	Gross=Empty.		Lbs. Sq. Ft. Kg. per Sq. M.	Lbs. H.P. Kg. per H.P.
1	Beardmore -	170	1,350	2,810 1,275	1,885 842	5·6 27·4	16·5 7·4
2	Rolls Falcon 3 -	275	2,000	2,848 1,292	... ...	7·0 34·2	10·4 4·65
3	Sunbeam Arab -	215	2,000	2,804 1,272	1,806 820	6·9 33·7	13·05 5·85
4	Siddeley Puma -	290	1,600	2,835 1,286	1,946 883	7·0 34·2	9·8 4·4
5	Rolls Eagle 7 -	322	1,800	3,499 1,587	... ...	8·0 39·1	10·9 4·9
6	„ „ 8 -	360	1,800	3,576 1,622	2,419 1,097	8·2 40·0	9·9 4·45
7	Siddeley Puma -	235	1,400	3,325 1,509	2,140 970	7·5 36·6	14·15 6·35
8	„ „ -	290	1,600	3,410 1,548	... ...	7·7 37·6	11·75 5·25
9	Liberty -	405	1,650	4,220 1,915	2,665 1,210	8·55 41·7	10·4 4·65
10	„ -	405	1,650	4,645 2,106	2,695 1,222	9·45 46·2	11·5 5·15
11	Rolls Eagle 8 -	359	1,800	4,337 1,968	2,732 1,240	8·9 43·5	12·1 5·4
12	„ „ 8 -	359	1,800	5,000 2,269	2,732 1,240	10·25 50·0	13·9 6·25
13	2 Libertys -	2 × 405	1,650	8,500 3,860	5,530 2,511	10·0 48·8	10·5 4·7
14	„ -	2 × 405	1,650	9,000 4,087	5,530 2,511	10·6 51·8	11·1 4·95
15	Beardmore -	170	1,350	3,037 1,380	2,066 940	6·2 30·3	17·9 8·0
16	2 Rolls Eagle 7 -	2 × 322	1,800	12,230 5,560	8,480 3,855	7·45 36·4	19·0 8·5
17	„ „ 8 -	2 × 359	1,800	13,360 6,073	8,302 3,775	8·1 39·6	18·6 8·35
18	Rolls Falcon 3 -	288	2,200	2,446 1,112	1,794 816	7·25 35·4	8·5 3·8
19	300 Hispano -	305	1,800	2,289 1,041	1,610 732	6·95 34·0	7·5 3·35

BRITISH AEROPLANES--Continued

AEROPLANE--Continued.							
No.	Make.	Type.	No. of Crew.	Dimensions.			
				Span. Ft. M.	Length. Ft. M.	Height. Ft. M.	Surface. Sq. Ft. Sq. M.
20	R.E. 8	Corps Recon.	2	42.7 13.05	27.8 8.5	10.8 3.3	388 36.1
21	S.E. 5	Fighter	1	28.0 8.55	21.3 6.5	9.4 2.85	249 23.1
22	S.E. 5A.	Fighter	1	26.7 8.15	21.0 5.4	9.5 2.9	247 23.0
23	Sopwith-Camel	Fighter	1	28.0 8.55	18.7 5.7	8.5 2.6	231 21.5
24	" "	Fighter	1	28.0 8.55	18.7 5.7	8.5 2.6	231 21.5
25	" "	Fighter	1	28.2 8.6	18.5 5.65	8.5 2.6	231 21.5
26	" "	Fighter	1	28.2 8.6	19.0 5.8	8.6 2.6	233 21.6
27	" Dolphin	Fighter	1	32.5 9.9	22.5 6.85	8.0 2.45	258 24.0
28	" "	Fighter	1	32.5 9.9	22.0 6.7	7.8 2.4	262 24.3
29	" Pup	Training	1	26.8 8.15	19.6 5.95	9.0 2.75	254 23.6
30	" "	Training	1	26.5 8.1	20.0 6.1	8.9 2.7	252 23.4
31	" Salamander I	Armoured Ground Fighter	1	30.0 9.15	18.8 5.75	8.6 2.6	267 24.8
32	Sopwith-Snipe	Fighter	1	30.1 9.15	19.8 6.05	8.8 2.7	270 25.1
33	" " with camel load	Fighter	1	30.1 9.15	19.8 6.05	8.8 2.7	270 25.1
34	Sopwith-Snipe, with extra petrol	Long Distance Fighter	1	30.0 9.15	19.4 5.9	8.9 2.8	269 25.0
35	Vickers Vimy	Night Bomber	2	68.1 20.8	44.0 13.4	15.0 4.6	1,328 123.5
36	" "	Night Bomber	2	68.1 20.8	44.0 13.4	15.0 4.6	1,328 123.5

D.E.D.A. (Unpublished Data) System
K. Forlane Matthews. Patents (provisionally protected). U.S. Patents applied for

BRITISH AEROPLANES—Continued

ENGINE—Continued.							
No.	Type.	Normal.		Weight.		Loading.	
		B. H. P.	R. P. M.	Gross = Empty.		Lbs. Sq. Ft. Kg. per Sq. M.	Lbs. H. P. Kg. per H. P.
20	R. A. F. 4A -	160	1,800	2,869	1,803	7.4	17.9
				1,305	820	36.2	8.0
21	Wolseley Viper	202	1,800	1,980	(1,384)	8.0	9.8
				900	630	39.1	4.4
22	200 Hispano -	210	2,000	1,953	1,322	7.9	9.3
				886	600	38.6	4.15
23	110 Le Rhône -	137	1,250	1,422	889	6.2	10.4
				646	404	30.3	4.65
24	130 Clerget -	125	1,250	1,453	929	6.3	11.6
				660	421	30.8	5.2
25	B. R. 1 -	150	1,250	1,471	962	6.4	9.8
				668	436	31.2	4.39
26	150 MonoGnome	150	1,225	1,523	993	6.55	10.15
				692	451	32.0	4.55
27	200 Hispano -	210	2,000	2,003	...	7.8	9.6
				910	...	38.1	4.3
28	„ „ -	212	1,800	2,000	1,391	7.65	9.45
				908	631	37.4	4.25
29	80 Le Rhône -	84	1,250	1,225	787	4.8	14.6
				556	358	23.4	6.55
30	100 MonoGnome	105	1,250	1,297	856	5.2	12.4
				588	388	25.4	5.55
31	B. R. 2 -	228	1,300	2,512	1,844	9.45	11.0
				1,140	837	46.1	4.9
32	„ 2 -	228	1,300	2,020	1,312	7.5	8.85
				918	596	36.6	3.95
33	„ 2 -	228	1,300	1,775	1,312	6.6	7.8
				806	596	32.2	3.5
34	„ 2 -	228	1,300	2,271	1,329	8.85	9.95
				1,030	603	43.2	4.45
35	2 Rolls Eagle 8	2 × 359	1,800	12,500	6,901	9.4	17.4
				5,670	3,130	45.9	7.8
36	„ „ 8	2 × 359	1,800	10,000	6,901	7.55	13.9
				4,536	3,130	36.9	6.25

FRENCH AEROPLANES

AEROPLANE.							
No.	Name.	Type.	Crew.	Span.	Length.	Height.	Total Surface.
1	A.R.	Reconn.	2	43·2	30·5	10·2	538
2	"	"	2	39·4	28·75	9·8	484
3	"	"	...	39·4	30·5	9·8	484
4	Breguet	"	2	47·2	29·6	10·8	560
5	"	"	2	46·0	29·2	10·8	527
6	"	Bomber	2	46·0	29·2	10·8	560
7	"	"	...	46·0	29·2	10·8	560
8	"	Fighter	2	57·8	32·5	12·8	632
9	Caproni	Bomber	2	73·4	36·1	12·8	1,076
10	Caudron G6	Reconn.	2	56·5	28·22	9·7	427
11	" R4	"	3	69·4	38·6	10·5	736
12	" R4	"	3	69·4	38·6	10·5	736
13	" R. II	"	3	58·9	36·8	9·2	583
14	Farman	"	2	57·8	30	12·5	559
15	Letord	"	3	59·1	36·6	12·15	660
16	"	"	3	59·0	36·6	12·15	660
17	Morane, Parasol	"	2	36·8	23·6	11·4	194
18	Nieuport	Fighter	1	27	19	7·88	161
19	"	"	1	27	21	7·88	161
20	Salmson	Reconn.	2	38·6	27·9	9·52	398
21	Schmitt	Bomber	2	58	31·5	11·8	645
22	Sopwith	Reconn.	2	33·6	25·6	10·25	344
23	"	"	2	33·6	25·6	10·25	344
24	"	Bomber	1	33·6	25·6	10·4	344
25	Spad	Fighter	1	25·8	20·1	7·23	192·5
26	"	"	1	25·8	20·1	7·23	193·5
27	"	"	1	...	...	...	...
28	"	"	1	26·3	20·4	7·55	215
29	"	"	...	26·3	20·4	7·55	215
30	"	Reconn.	2	36·8	25·4	8·54	323
31	Voisin, L.C.	"	2	48·2	34·8	10·5	452
32	" L.A.P.	Bomber	2	61·7	36·2	11·5	678
33	"	"	2	61·7	36·2	11·5	678
34	"	Fighter	2	61·7	36·2	11·5	678

D.E.D.A. (Detachable Data) System
 R. Bvriac Mathies' Patents (provisionally protected). U.S. Patents applied for.

FRENCH AEROPLANE DATA 629.13.52.2(44)

FRENCH AEROPLANES—Continued

ENGINE.							
No.	Type.	Normal.		Weight.		Lbs. per Sq. Ft.	Lbs. per H.P.
		H.P.	R.P.M.	Gross.	Empty.		
1	Renault, 8 Gd -	185	1,450	2,750	1,782	5.12	17.2(2)
2	" 8 G.dy	200	1,600	2,750	1,815	5.75	13.8
3	Lorraine, 8 A -	185	1,600	...	...	...	...
4	Renault, 12 F.cx	300	1,600	3,379	2,222	6.05	11.4(2)
5	" 12 F.cy	310	1,600	3,379	2,222	6.4	10.9
6	" 12 F.cx	300	1,600	3,885	2,279	6.97	13.0
7	...	...	...	3,885	2,279	6.97	13.0
8	Renault, 12 F.b (Salmson, 9 A)	265	1,400	4,235	3,067	6.76	16.1
9	{ 2 Rhone, 9 Ja }	...	...	6,248	4,378	5.82	15.0(2)
10	" 9 J6 -	2 x 130	1,280	3,168	2,068	7.45	12.2
11	2 Renault, 12 Bb	2 x 140	1,450	5,148	3,784	6.85	18.4
12	2 H.S., 8 Aa -	2 x 175	1,700	4,752	3,388	5.95	13.5
13	" 8 BDa -	2 x 215	2,150	(1)4,763	3,124	8.2	11.0
14	Renault, 8 Gb -	160	1,300	2,475	1,650	4.43	15.6(2)
15	2 H.S. 8 Aa -	2 x 175	1,700	4,173	2,759	6.34	11.9
16	" 8 Bda -	2 x 215	2,150	(1)5,203	3,564	7.48	...
17	Rhone, 9 Ja -	120	1,250	1,612	952	(1)8.4	13.4
18	" 9 Ja -	120	1,250	1,232	825	7.8	10.2
19	" 9 Jb -	130	1,280	1,203	781	7.48	9.24
20	Salmson, 9 Z -	270	1,600	2,798	1,676	6.97	10.4
21	Renault, 12 Fc.	265	1,400	4,615	2,855	7.18	17.4
22	Clerget, 9 Bb -	135	1,250	2,037	1,157	5.95(2)	15.1
23	Rhone, 9 Jb -	130	1,280	2,011	1,181	5.95(2)	15.4
24	Clerget, 9 Bb -	135	1,250	2,200	1,320	6.35	16.3
25	H.S., 8 Aa -	175	1,700	1,551	1,100	8.1	9.0(2)
26	" 8 Ab -	205	1,800	1,551	1,100	8.1	9.0(2)
27	" 8 C -	220	2,150	...	...	...	...
28	" 8 Ba -	220	2,150	1,815	1,254	8.46	8.25
29	" 8 BEc -	235	2,150	1,815	1,254	8.46	8.25(2)
30	" 8 Bc -	215	2,150	2,310	1,485	7.18	11.0
31	Renault, 8 Gcx -	190	1,500	2,899.6	2,129.6	...	15.2
32	Peugeot, 8 Aa -	...	...	4,103	2,893	6.15	18.7
33	Renault, 12 F.cx	300	1,600	4,103	2,893	6.15	18.7(2)
34	Peugeot, 8 Aa -	220	2,050	4,103	2,893	6.15	18.7

ITALIAN AEROPLANES

No.	Make.	Type.	Crew.	Dimensions.							
				Span.		Length.		Height.		Surface.	
				Ft.	In.	Ft.	In.	Ft.	In.		
1	N1.2 -	Fighter	1	26	9	19	2	7	10	158	
2	HO -	"	1	27	11	19	2	8	4	184	
3	SPAD VII -	"	1	25	7	20	0	7	5	188	
4	SPAD XIII	"	1	27	1	20	4	7	7	222	
5	A.1 -	"	1	25	2	21	4	9	4	221	
6	SP.3 -	Reconn.	2	48	4	35	0	11	8	646	
7	SAML -	"	2	39	8	27	11	9	10	420	
8	Sl.A7.B1 -	"	2	43	9	29	10	10	4	517	
9	PE -	"	2	39	0	29	4	10	2	495	
10	SVA -	"	1	26	3	26	3	8	8	237	
11	S.8 (Hydro-plane)	"	2	41	9	32	0	11	2	495	
12	M.8 (Hydro-plane)	"	2	52	6	32	8	10	11	449	
13	FBA -	"	2	47	7	33	2	10	11	438	
14	L.3 -	"	2	53	3	34	10	10	4	463	
15	SP.4 -	Bomber	3	65	0	35	2	11	8	836	
16	CA.3 -	Triplane	3	72	11	36	4	12	7	1,055	
17	CA.4 -	Bomber	4	98	2	43	0	20	8	2,186	
18	CA.4 -	"	4	98	2	43	0	20	8	2,186	

DF-DA (Detachable Data) System
R. Borlase Matthews' Patents (provisionally protected). U.S. Patents applied for.

ITALIAN AEROPLANE DATA 629.13.52.2(45)

ITALIAN AEROPLANES—Continued

ENGINE.							
No.	Type.	Normal.		Weight.		Loading.	
		H. P.	R. P. M.	Gross.	Empty.	Lbs. per Sq. Ft.	Lbs. per H. P.
1	Le Rhone	125	1,200	1,306	865	7.95	10.14
2	"	125	1,200	1,272	853	6.74	10.16
3	HS-34	175	1,600	1,554	1,102	8.07	8.86
4	HS-34	200	2,000	1,888	1,325	8.31	9.44
5	SPA	220	1,600	1,978	1,472	8.7	8.82
6	FIAT-A12	260	1,500	3,712	2,720	5.74	14.25
7	"	260	1,500	2,946	21,120	7.02	11.31
8	"	260	1,500	3,462	2,360	6.7	13.23
9	"	260	1,500	3,390	2,510	6.85	13.04
10	SPA-6A	205	1,600	2,027	1,532	8.55	9.92
11	1F-V4B	190	1,450	3,031	1,985	6.10	15.85
12	"	190	1,450	3,142	1,985	7.79	16.02
13	"	190	1,450	3,165	2,110	7.02	17.4
14	"	190	1,450	2,911	1,900	5.83	15.2
15	21F-V4B	190	1,450	5,133	3,750	6.55	14.3
16	31F-V4B	190	1,450	7,304	5,100	6.9	12.8
17	3FIAT-A12 B15	290	1,600	13,559	8,050	6.15	15.55
18	31F-V5	270	1,500	13,289	7,780	5.88	15.86

GERMAN AEROPLANES

Type.	Span.		Chord.		Gap.	Length.		Area of Main Planes.	Engine.	Weight.	
	Top.	Bottom.	ft.	in.		ft.	in.			Empty.	Load.
A.E.G. (G) - (G)	57.7	ft. in. 57.7	6.7	ft. in. 6.7	ft. in. 8.6 to 7.5	30.4	sq. ft. 800	2-260 H.P. Mercedes	lbs. 5250	1760	
Ago - (D)	32.1	29.1	5.4	5.4	5.3	22.6	...	110 H.P. Uherusel	...	...	
Albatros - (C III)	41	36	6.1	6.1	6.4	26.3	...	...	1863	968	
Albatros - (C VIII)	41.6	37.7	6 to 5.4	6 to 5.4	6.0	28	446	220 H.P. Mercedes	2265	980	
Albatros - (D II)	28.2	26.10	5.4	5.4	5.3	23.3	255	170 H.P. Mercedes	1550	495	
Albatros - (D III)	29.7	28.8	5.0	5.0	4.8	24.0	241	170 H.P. Mercedes	1475	470	
Albatros - (D V)	29.7	28.8	5.0	5.0	4.7 to 4.5	24.0	221	170 H.P. Mercedes	1368	480	
Albatros - (G)	29.6	...	...	...	...	24.0	221	160 H.P. Mercedes	1470	470	
Aviatik - . -	41.0	35.4	6.1	6.1	6.4	26.3	...	170 H.P. Mercedes	1680	490	

GERMAN AEROPLANE DATA 629.13.52.2(43)

Aviatik - (G)	43	6	...	...	...	25	11	455	220 Benz	2265	980
D.F.W. - (CV)	43	5	42	0	5-9	5	8	455	220 H.P. Benz	2165	1080
Fokker E III -	32	11	...	...	...	24	0	...	100 Uberusel	920	480
Fokker Triplane	23	8	18	11	3	4	2 5 $\frac{1}{2}$ and 2 5 $\frac{1}{4}$	205	100 Uberusel	829	430
Friedrichshafen (G)	62	0	18	11	3	4	18-1	205	2-220 H.P.	4400	2300
Gotha - (G IV)	75	0	70	6	7-3	8-6	42-0	910	2-260 H.P. Mercedes	5700	3130
Halberstadt - (D III)	29	0	26	0	5-0 to 5-7	4-2	24-0	259	120 H.P. Argus	1338	440
L.V.G. - (D IX)	42	3	37	4	5-0 to 5-3	5-6	26-8	405	160 H.P. Mercedes	1863	980
Pfalz - (D III)	30	11	...	...	...	...	...	230	160 H.P. Mercedes	1580	475
Roland - (D II)	29	6	28	0	4-75	4-3	22-6	...	160 H.P. Mercedes	1450	460
Rumpler - (C III)	40	4	36	5	5-8 to 5-6	5-9	26-0	386	160 H.P. Mercedes	1828	950
Rumpler - (C V)	40	9	37	0	5-6	5-9	25-10	400	260 H.P. Mercedes	1850	950
Rumpler - (G)	38	6	35	0	5-7	5-9	25-10	385	260 H.P. Mercedes	1800	900

AMERICAN AEROPLANES

Make.	Span.		Chord.		Gap.		Length.	Area of Planes.	Engine.	Weight.	
	Top.	Bottom.	ft. in.	ft. in.	ft. in.	ft. in.				Machine.	Load.
Amer. Aircraft Co.	47	3 44 0	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	sq. ft.	2-100 Hall-Scott	lbs. 1600	lbs. 930
Atl. Aircraft Co. Twin	48	0 48 0	48 0	48 0	6 0	6 0	7 0	28 6	2 Aeromarine 85 H.P.	...	...
Aeromarine M-1	37	0 33 0	37 0	33 0	...	...	...	420	100 H.P.	...	...
Benoist H-17	45	0 45 0	45 0	45 0	5 3	5 3	5 0	24 0	Roberts 100 H.P.	1700	600
Benoist K-17 Pusher	75	0 65 0	75 0	65 0	5 3	5 3	5 0	...	2 Roberts 100 H.P.	2700	1300
Benoist E-17	45	0 45 0	45 0	45 0	5 3	5 3	5 0	...	Roberts 100 H.P.	1700	600
Benoist C-17 Pusher	75	0 65 0	75 0	65 0	5 3	5 3	5 0	...	2 Roberts 100 H.P.	2800	1200
Burgess Dunne (New) P	46	6 46 6	46 6	46 6	6 9	6 9	6 6	31 0	140 H.P.	...	...

AMERICAN AEROPLANE DATA 629.13.52.2(73)

Burgess Dunne Seaplane Pusher	46 0	...	...	...	23 0	...	100 H.P.	...	650
Burgess Dunne Navy Seaplane Pusher	45 2	...	...	...	21 10	...	140 H.P.	...	750
Burgess Hydroaeroplane	46 9	...	...	...	30 6	...	100 H.P.	...	640
Burgess Land Machine	46 9	...	...	...	30 6	...	100 H.P.	...	860
Burgess Land Machine	49 0	...	...	...	27 6	...	100 H.P.	...	1000
Curtiss JN 4-B	43 7 $\frac{3}{8}$	33 11 $\frac{1}{4}$	4 11 $\frac{1}{2}$	5 2 $\frac{3}{16}$	27 3	359.69	Curtiss OX 90 H.P.	1400	585
Curtiss Twin JN	52 9 $\frac{1}{2}$	43 1 $\frac{3}{4}$	4 11 $\frac{1}{2}$	5 2 $\frac{1}{2}$	29 0	450.28.2	Curtiss OXN 200 H.P.	2225	1040
Curtiss R4	48 4 $\frac{1}{2}$	38 5 $\frac{1}{4}$	6 3 $\frac{1}{16}$	6 2 $\frac{1}{4}$	28 11 $\frac{3}{4}$	450.52	Curtiss V2 200 H.P.	2300	1020
Curtiss N-9	53 3 $\frac{3}{8}$	43 0 $\frac{3}{8}$	5 0	5 0	29 10	496.13	Curtiss OXN 100 H.P.	2000	510
Curtiss F	45 2	35 0	5 2	6 11	28 0	420	Curtiss OX 90 H.P.	1500	600
Kyle Smith PI	32 0	22 0	4 6	4 6	23 9	245	6 Cylinder Radial	625	600
Lanzius L-1	38 0	38 0	5 6	5 3	25 0	400	Diesenberg 140 H.P.	1400	800

AMERICAN AEROPLANES—Continued

Make.	Span.		Chord.		Gap.		Length.		Area of Planes.	Engine.	Weight.	
	Top.	Bottom.	ft.	in.	ft.	in.	ft.	in.			Machine.	Load.
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	sq. ft.		lbs.	lbs.
Lanzius L-2	28	0	28	0	4	0	4	7	220	Duesenberg 140 H.P.	1200	800
L. W. F.	...	...	...	...	...	...	6	6	480	Thomas 135 H.P.	...	...
Lawrence-Lewis A-1	30	0	...	...	6	0	4	8	25	0	1750	800
Lawrence-Lewis B-1	42	0	...	...	7	6	5	8	29	0	2200	1500
M. F. P.	45	0	38	3	5	3	5	6	27	0	...	...
N.Y. Aero Constr. Co. A-1	73	0	44	0	Top 7' 6" Bot. 6' 6"		6	9	37	0	2822	1700
N.Y. Aero Constr. Co. A-2	73	0	44	0	Top 7' 6" Bot. 6' 6"		6	9	34	0	2472	2050

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Pacific Aero Products	52 0	43 6	5 9	6 6	27 5	480	Hall-Scott 125 H.P.	2750	700
S. S. Pierce Co.	26 0	20 0	4 0	5 6	20 0	184	S. S. Pierce B-35-40 H.P.	660	...
Standard H-3	40 1	40 1	6 6	6 6	27 0	491	Hall-Scott 140 H.P. A-5-a	2700	800
Standard J	44 0	32 0	6 0	5 11	26 7	433	Hall-Scott 90 H.P. A-7	1750	500
Standard D Twin	62 4	49	7 0	7 0	33 6	760	2 Hall-Scott A-5a, 140 H.P. each	3300	1350
Standard Speed Scout	26 6	26 6	5 0	5 6	22 7 $\frac{3}{4}$	225	Hall-Scott 125 H.P. A-9	1192	425
Sturtevant S-4	49 6	49 6	7 0	6 9	28 0	620	Sturtevant 5-A, 140 H.P.	2025	525
Thomas R. D.-5	52 9	34	5 6	5 3	29 9	465	Thomas Model 8 135 H.P.	2500	1100
United Eastern Aero- plane Corp H-M	39 0	30 0	5 6	6 0	25 6	350	Curtiss OXX-2 100 H.P.	1200	800
United Eastern Aero- plane Corp A-M	42 0	37 0	6 0	6 0	29 6	436	Curtiss OXX-2 100 H.P.	1430	500

AMERICAN AEROPLANES—Continued

Make.	Span.		Chord.	Gap.	Length.	Area of Planes.	Engine.	Weight.			
	Top.	Bottom.						Machine.	Load.		
	ft.	in.	ft.	in.	ft.	in.	sq. ft.	lbs.	lbs.		
United Eastern Aero-plane Corp A-N	45	0	45	0	6	0	28 3	482	Hall-Scott 125 H.P. A-5	1550	900
Verville Gamma SP	40	0	34	0	5	0	25 10	350	Curtiss OXX-2 100 H.P.	1500	450
Verville Beta Pusher	43	0	37	0	6	0	28 7	400	100 H.P.	1640	350
Verville Gamma LP	40	0	34	0	5	0	25 0	350	100 H.P.	1360	600
Wittelman TT	42	0	34	0	5	6	27 2	391	Hall-Scott A-7, 90 H.P.	1460	550
Wright-Martin R	50	8	36 10		5	6	26 8	458	Hall-Scott A-5, 125 H.P.	2005	880
Wright-Martin V	39	8.5	39 8.5		5	9.5	27 2	430	Simplex Model A Hispano- Suiza 150 H.P.	1725	805

AEROPLANE INSIGNIA

In place of a flag, which would be unsuitable, the aeroplanes of the belligerent Powers bear distinctive markings, based on the colours of the flag of the country they represent. The early British Naval seaplanes used to employ the design of the Union Jack, but this was subsequently replaced by a red circle, or more recently by a red centre, surrounded first by a white ring (or the natural colour of the fabric), and then by a blue ring—which is the standard for the Royal Air Force.

The position of these markings is $\frac{1}{4}$ of the span from the tips on the upper surface of the upper plane, and in similar positions on the underside of the lower plane. One mark is also placed on each side of the body, between the aviator's seat and the tail of the machine. The ring markings are not, however, employed on the rudders. In this latter position it is usual to employ striped markings, *e.g.*, Great Britain uses vertical blue, white, and red stripes. France has red, white, and blue vertical stripes on her aeroplane rudders, with circles of reverse colouring to the British in other positions. The Belgian, Roumanian, and Serbian colours are similar to the French, though formerly the Belgians employed their national colours of black, yellow, and red—the black being at the centre. The centre circle and the rear part of the marking on a rudder are always similar.

The Russian marks correspond to their flag, *i.e.*, lateral stripes of white, blue, and red—white being at the top or leading edge of a plane. On some of the later machines the circle system of marking has been adopted, hence the machines of all the Allies are alike in that they all use circles. The Italian circle mark has a red centre, surrounded by a white ring and green outer circle.

The U.S.A. mark on the planes was a five-pointed white star with a red centre on a circular background of blue. The marking has now been changed. Rudder marks are blue, white, and red stripes.

The German, Austrian, and Turkish distinctive mark is the well-known German cross on a white ground. The earlier Turkish machines, however, bore a white star and crescent on a red ground. In addition to the German cross, the Austrian machines often bear the national white and red stripes painted on the extremities of the wings. As well as the national emblems, the machines usually carry a number and class mark to indicate the service upon which they are engaged.

Experiments are being made to obtain paint colours that make an aeroplane on the ground as invisible as possible from an aeroplane overhead. Similarly, it would be advisable to use paint for the under surfaces, thus reducing the visibility to enemy anti-aircraft guns, or at least increasing the difficulty of range-finding. Many of the large soaring birds are difficult to distinguish at considerable heights, owing, undoubtedly, to the natural colourings of the under surfaces of their wings and bodies; though, on the other

hand, they often become easily visible when they circle and cant up, thus catching the reflection of the sun.

DISTINGUISHING FEATURES OF AEROPLANES

Probably the best way to ascertain the particular type of a machine is, in the first place, to notice whether or not it is a tractor biplane with a single engine. If it is not, it can be quickly placed into a comparatively small class, which comprises pusher biplanes, multi-airscrew machines, monoplanes, and triplanes. Purely experimental machines must be omitted for the time being, as they can hardly be called types until considerable numbers are in use.

Pusher Biplanes.—The **F.E.2B**, **F.E.2C**, **F.E.2D**, all have a small triangle above the elevators and tail planes. The tail booms taper into a vertical knife edge. The **F.E.8** has a cruciform tail, and the booms taper to a horizontal knife edge. The **Maurice Farman, 1913**, is easily recognisable with its characteristic longhorn landing gear; and likewise the **Maurice Farman, 1914**, with its short-horn landing gear. The **Henry Farman** has a short lower main plane and a monoplane elevator supported by booms, which latter taper to a vertical knife edge. The **Voisin** has a cruciform long span, short chord tail, and its main planes have a very long span. The **Vickers** has a round bullet-shaped nacelle, well raised from the main plane.

Multi-Airscrew Machines.—The features which distinguish these machines are, in the case of the **Handley-Page**, the biplane tail, balanced ailerons, projecting beyond the ends and trailing edges of the wings, and bulky fuselage with round nose, extending well in front of the main planes. The **A.E.G.** is similar to the single-engined **A.E.G.**, with the trapezoidal wings and fluted trailing edges. The **Caproni R.E.P.** has twin fuselages. The **Caudron R.4** is distinguishable by its three pairs of interplane struts outside each engine nacelle; the **Caudron G.6** by its small lower plane; and the **Caudron G.4** by the fact that it has no fuselage. The **Gotha** has markedly swept-back wings; while the outstanding feature of the **Letord** is its back-staggered main planes. The **Morane-Saulnier** has four pairs of interplane struts on the outer side of each engine nacelle, the outer two pairs of which are inclined. The **Salmson-Moineau** is unique in that it is a single engine machine, having two geared propellers. The propellers are each supported on "X" struts.

Monoplanes are easily recognisable, as there are only three makes in regular use to-day, the **Morane-Saulnier** (3 types), the **Fokker**, and the **Bristol**. The **Parasol Morane-Saulnier** is readily distinguishable owing to the parasol-like position of the main planes well above the fuselage. In the case of the **Marks 11** and **13** machines, the roots of the wings are midway up the fuselage. All three fuselages are round, tapering to the tail. The rudders and

DE-DA (Detachable Data) System
R. Barlow Matthews' Patents (provisionally protected). U.S. Patents applied for.

top fins form a triangle. The **Fokker** has a rectangular section fuselage, with a comma-like rudder, and the root of the wings is level with the top of the fuselage. The elevators are lozenge-shaped. The **Bristol** monoplane can readily be distinguished from the above by its Bleriot form, rounded wing tips.

Triplanes.—The only machine of this class that exists in any number is the **Sopwith**. The fuselage is placed between the middle and the lowest planes. There is only one wide strut on each side of the fuselage.

Tractor Biplanes (with single engine).—As the majority of modern machines are of this type, it becomes a more difficult matter to distinguish one from another. German machines are dealt with in Division 629.13.52, "Typical Aircraft." Having ascertained that a particular aeroplane is a tractor biplane, the next step is to look at the **Undercarriage**. If not a vee type, the machine will probably be either an **Avro** (rotary engine), an **Armstrong-Whitworth**, or an **R.E.7** (rounded wing tips and short span to lower plane). The design of the **Tail** is perhaps the next most striking feature of a machine. Attention should be given (1) to the number of rudders, their position relative to the fuselage, and their shape; (2) the number of fins, and their positions and shapes; (3) the shape of the tail plane and elevators, and whether the latter are divided or not, according to the position of the rudder.

The details of construction of the **Main Planes** of a machine follow next in importance:—(a) The proportion of the span of the lower plane to that of the upper; (b) the number of struts on each side of the fuselage; (c) whether the top plane is staggered (either forward or backward) or not; (d) the general shape, viz., whether rectangular, rectangular with rounded tips, trapezoidal, etc.; (e) whether there is sweep-back (arrow-like form) or not; (f) the position of the fuselage relative to the planes; (g) whether the aileron trailing edges are in line with the trailing edges of the main planes, or extend beyond.

When a machine is viewed chiefly in plan, the wing tips, tail planes with elevators, and the front of the fuselage are the main guides. As viewed from one side, the shape of the rudder and fin are the most characteristic features, though the shape of the fuselage often gives some assistance.

Lastly, any other noteworthy general characteristics, such as:—(1) The shape of the fuselage or of the nacelle, and the amount of projection of the latter beyond the leading edges of the main planes; (2) the relative proportion of the span of the machine to its length; (3) the cowling; (4) the position of the airscrew relative to the planes.

It makes quite a considerable difference as to whether a machine is seen in plan or side view only, as certain characteristics may be masked by other portions of a machine. Nearly every make of engine can be distinguished, by the experienced, by its sound. Rotary engines as a class give a continuous exhaust sound, quite unlike that of the stationary engines.

DISTINCTIVE FEATURES OF TRACTOR BIPLANES**(With Single Engines)**

- A.R. or A.L.D.** - Fuselage between the planes, back stagger, trapezoidal main planes and tail, square rudder.
- B.E.2C and 2D** - Rounded wing tips, rectangular tail, triangular fin and oval rudder (2 seater).
- B.E.12** - - Rounded wing tips, trapezoidal tail, convex fin and oval rudder (single seater).
- Breguet** - - Swept back main planes, triangular tail plane with balanced trapezoidal elevators.
- Bristol Scout** - One pair of struts, rotary engine, otherwise similar to Martinsyde.
- Bristol Fighter** - Fuselage raised above lower planes, which have vertical fins at their roots. Fuselage finishes in horizontal knife edge.
- D.H.4** - - Rounded wing tips, two pair struts each side, balanced rudder.
- D.H.5** - - Marked back stagger, rounded fuselage.
- D.H.6** - - Marked square corners of wings and tail.
- Martinsyde** - Rudder and fin have an ear-like contour, wide nearly trapezoidal tail plane, car-like cowl in front of fuselage.
- Morane-Saulnier** One pair of struts each side, rounded body, lozenge shaped elevators, no tail plane.
- Nieuport** - - Small lower planes, set at a dihedral angle, Vee interplane struts.
- Sopwith** - - Sopwith fins always have semicircular fronts.
- Spad S.S.** - - Fluted trailing edges, tail planes triangular, triangular fin.
- Spad T.S.** - - Swept back main planes, fin, and rectangular rudder form a large triangle.
- Vickers Scout** - Semicircular wing tips, one pair struts each side, semi-oval rudder.

Those who would like to go into this matter of the identification of aeroplanes in a more detailed and practical manner are referred to "The Aircraft Identification Book" (see Bibliographical Division).

CHARACTERISTICS OF GERMAN AEROPLANES

The Taube type of aeroplane has disappeared, though it seems to have left its traces on such details as the shape of the tail unit, and the arrow-like disposition of the main planes, the dihedral angle of which is also retained. However, the majority of present-day German machines still have a characteristic appearance which is all their own, though the more recent fast scouts and fighting

machines seem to be closer copies of the designs of the Allies. After all, the only reliable guide is the German black cross on the lower planes (see page 451) or hostile action.

The machines of the Central Powers are generally tractor biplanes (a prominent but special exception is the Gotha, which, however, has the characteristic fuselage of a tractor machine). The spans and chords of the upper and lower planes are usually equal, or nearly so. The upper and lower planes are both usually set at a slight dihedral angle (the Albatros D3, has a dihedral angle on the lower plane only), and are slightly swept back, in arrow-like fashion (this sweep-back is very marked on the Gotha). Another marked feature is the almost universal trapezoidal shape of the wings, generally accompanied by projecting ailerons, which latter emphasise the arrow-like appearance of the machines. (The Ago machine has converging spars, and consequently triangular-shaped wings—with the apex removed.) The spatulate or lobe-shaped rudders are often fixed above the fuselage, and so the elevators are not then divided in the middle. The tail planes are either triangular (isosceles) or well rounded in plan, with spatulate or semicircular double portion elevators, in those cases where the elevators are divided and the rudder mounted above the fuselage. The overall length of the machine is generally short, as compared with the span. Vertical stationary type engines are generally fitted as standard.

LEGAL

629.13:34

Legal text-books do not at present throw any light upon the position of an aeroplane in law, which is, of course, due to the fact that it does not proceed along a highway. In the case of locomotion of any form along public roads, the whole matter is closely hedged in with rules of law, the outcome of centuries of experience, so that all questions of liability for damage done are fairly easily settled.

Trespass

There is a case on record in which it was shown to be a trespass to pass over a man's land in a balloon since a man owns his land *usque ad cælum*.

If in descending, injury is done to property, the aviator may be sued in *tort*.

Liability of an Aviator

If an aviator lands in a place where the public have access, and does damage to some person or persons, he is of course liable under common law. It is not such an easy point to determine the question of liability when the person run down is trespassing on private grounds, assuming that the aviator is also a trespasser. As regards such accidents at an aviation meeting, apparently the aviator is not held responsible, as is indicated in the next paragraph.

Liability of Aviation Meeting Organisers

No liability accrues to the organisers of aviation meetings for an accident happening to a spectator, as is indicated from the following, which is abstracted from a book entitled "The Law of Torts": "The breach of duty which will render an owner of premises liable to a person coming there on business consists either in (1) neglecting to give warning of hidden sources of danger which are known to him; or in (2) omitting to take proper precautions to acquire knowledge of the danger, and having acquired it, to give proper warning. As towards a bare licensee not coming on business, the owner is liable only for negligence of the first kind. But as towards either class of licensees, the owner having given due warning, is free from all responsibility."

Aerial Navigation Acts, Rules, and Orders

The Acts, Rules, and Orders dealing specifically with aviation matters are as follows:—

Aerial Navigation Act, 1911.

Aerial Navigation Act, 1913.

Statutory Rules and Orders, 1913, No. 228.

Statutory Rules and Orders, 1913, No. 243.

Order dated 1913 re Aerial Navigation Act, 1913.

Statutory Rules and Orders, 1914, No. 725.

Statutory Rules and Orders, 1914, No. 726.

Air Force (Constitution) Act, 1917.

DE-DA (Detachable Data) System.
R. Borlase Matthews' Patents (provisionally protected). U.S. Patents applied for.

PARACHUTES FOR AEROPLANES

Hitherto parachutes have been nothing more than a balloon adjunct. Recently, however, considerable thought has been expended upon their use in conjunction with aeroplanes—an entirely different proposition. From the crude toy of a few years ago, the acrobatic appliance of the sensation-mongering showman has developed into a scientific life-saving apparatus. Only those who have been in touch with the makers and users of recent appliances realise what a very specialised subject their design and application has become to-day, requiring much technical knowledge and experience.

The great difficulty that is encountered in launching a parachute from an aeroplane, as compared with a drop from a balloon, is due to the high speed of the aeroplane. When a parachute leaves an aeroplane, it is met by a powerful horizontal force approximately three times as great as its normal velocity of fall, hence the object to be aimed at, is to so design a launching apparatus that the parachute can blow straight down wind and open without any whipping action or entanglement of the rigging cords (which latter is a very serious danger). At the same time precautions must be taken to obtain a sufficiently rapid opening which should be completed before the downward velocity has obtained too great a magnitude. Full support should be given at a very early period in the descent, and also the parachute must be well out of the way of the tail when it opens.

Types.—The best known British types are the Guardian Angel (Calthrop), Spencer, Mears, etc. French types are S.T.Aé., Robert, Caquot, Ors, etc. German types are Heinecke, Fokker, etc. The U.S.A. have evolved certain special service types of parachute designs, all of which, however, are merely a combination of the best features of European practice.

Dimensions.—The diameter of a parachute when open should not be under 21 ft. (6·4 m.); in practice, the dimensions vary from 22 ft. (6·7 m.) to 33 ft. (10 m.). In cases where the parachute is made of cotton it should not be less than 23 ft. (7 m.).

DIMENSIONS OF TYPICAL GERMAN PARACHUTES

Diameter of Parachutes.		Rigging Band.	Length from Vent to Rigging Band.	Circumference of Vent.	Rings.	Panels per Ring.
Ft.	In.	Ft.	In.	Ft.	In.	
19	5	58	4	13	4	20
21	0	63	4	13	4	20
21	0	63	4	13	0	20

PANEL DIMENSIONS OF TYPICAL GERMAN PARACHUTES

Diagram of Parachute.	Ring No. 1	Ring No. 2.	Ring No. 3.	Ring No. 4.
	In.	In.	In.	In.
Ft. In.				
19 5	1'6 × 40 × 13	13 × 40 × 28	23 × 40 × 32	32 × 40 × 35
21 0	2'2 × 60 × 20	20 × 64 × 30	30 × 36 × 38	...
11 0	2'1 × 76 × 25	25 × 80 × 38	...	...

Note.—The side of each panel is cut on a curve, as it has to form a portion of a spherical surface.

The rigging of the first of the above German parachutes consists of twenty lines, each a half inch in circumference and 22 ft. 5 in. long. These lines run from the rigging band to a 4-in. metal ring. Below the metal ring, and attached to it, are two first bridles of 1½ in. circumference and 18 in. long. This rigging may be taken as typical of that of most parachutes. Sometimes tapes are utilised (*e.g.*, in the Guardian Angel parachute) instead of cords, to facilitate launching, and to prevent the entanglement of the rigging in a horizontally moving current of air.

The most usual shape is a section of a sphere, having a radius of 23 ft. (7 m.) to 33 ft. (or 10 m.). Very curved shapes have been tried, but they are found to give rise to a bad pendulum motion; while there is a good deal of side motion or slipping with the flat type, this latter type falls very slowly. The pendulum motion is also characteristic of a lightly loaded parachute. In the case of a parachute with a radius of 9·10 m. and of 7·75 m. diameter, the rise of the chord of projection of the sphere would be 1·2 m. The area allowed in a parachute should be about 4 sq. ft. of fabric per lb. weight supported, *e.g.*, a parachute of 28 ft. diameter (615·7 sq. ft. superficial area), which, in actual use, has a diameter of about 21 ft. (346·3 sq. ft. projected area), would carry 154 lbs., including the weight of the parachute itself. This can be deduced by referring to the formula given in this "Aviation Pocket-Book," which gives the air resistance of a plane in lbs. as $0\cdot0032 SV^2$, where S is the area in square feet, and V the velocity in miles per hour. A slight variation of this formula is sometimes quoted, owing to the fact that the constant $0\cdot0032$ decreases as V increases, and *vice versa*; it is $0\cdot00286$ for 90 miles, and $0\cdot00327$ for under 25 miles per hour. Dr T. E. Stanton has, however, shown that $0\cdot0032$ is a good mean value.

Compared with an ordinary convex wing, a parachute has, naturally, a greater degree of convexity, and it is found in practice that the most suitable formula is $0\cdot00125 SV^2$, or $\frac{1}{800} SV^2$, where S

is the superficial area of the silk body, and V the velocity in feet per second.

Weights.—The weight of the fabric usually varies from 6 to 12 lbs. The weight of the rigging may weigh from 4 to 8 lbs. The total weight of a parachute varies from 12 to 32 lbs. To this must be added the weight of the parachute case, launching disc, aeroplane attachment fittings, or the like, which may in an extreme case mount up to 68 lbs.

English parachutes are invariably made of (either natural or Japanese) silk, whereas all other nationalities employ parachutes of cotton as well. The silk usually employed weighs from 60 to 90 gm. per square metre. Silk is preferred on account of its lightness, greater strength for a given weight and compactness. It is quite a usual practice to fireproof parachute fabric.

Installation on Aeroplane.—This very largely depends on the launching device. The positions that have been adopted are: (a) under the seat; (b) as a cushion (this position is rather apt to cause matting of the fabric); (c) at the back of the seat; (d) as a knapsack on the aviator's back; (e) on the side of the cockpit; (f) on the top of the fuselage immediately behind the aviator; (g) in a special opening provided in the side of the fuselage; (h) underneath the fuselage, either suspended (this is objectionable on account of the head resistance) or in an opening constructed in the bottom of the fuselage. A new form of the Calthrop parachute is placed in one of the main planes.

The fixing of the parachute case and the connections with the aviator should be such as to permit him to jump clear by either side of the aeroplane without the necessity for the operation by hand of special slip catches. If the latter device is incorporated at all, it should be automatic in action.

Launching.—A modern aeroplane parachute, such as the Guardian Angel, is guaranteed to open and carry its load at the safe landing speed of 15 ft. per second from any height above 200 ft., in fact, it has done it in less than 125 ft., whereas ordinary balloon types require nearly 300 ft. to open, and should not be used for heights under 2,000 ft. Failure to open, or delayed opening of a parachute, is generally due to the formation of a partial vacuum within the parachute body. This is caused by the rushing by of the external air, producing an ejector effect through the hole in the top of the parachute. After the parachute has extended and is in descent, this central hole acts as a form of rudder. It does this by establishing a stable flow of air, thus preventing violent oscillations and a possible overturn. In the case of this special parachute, the construction is such that it emerges from its case; the small hole (about 10 in. diameter) at the top is protected by a cover, while the body encloses a cylindrical column of air 2 ft. wide, many times greater in area than the hole at the apex. This column of air is converted by the fall to a bun-shaped cushion of compressed air, which instantly extends the body of the parachute to its utmost

limits of expansion. The column of air is obtained through the pleated periphery of the silk body having to pass over the edges of the launching disc, which is 2 ft. in diameter. As assembled for use, the silk body is retained in its symmetrically pleated and folded condition upon the launching disc by threads, which are broken in sequence by the fall of the aviator.

An alternative method for launching a parachute from an aeroplane, instead of employing metal launching discs, is that known as the Mears' system, which, in principle, is exceedingly simple. It comprises a strip of canvas about 10 ft. long and 9 in. wide, which is rolled up with the folded parachute. One end of this strip of canvas is attached to the aeroplane by about 30 ft. of rope, and when a drop is made, owing to the fact that one end of this strip of canvas is attached to a fixed point on the aeroplane, the parachute is bound to unroll steadily and uniformly, while the central opening at the top of the parachute is kept closed till the last moment. It has, however, the objection of extending the depth of the free fall of the aviator before any support is received, by the depth of the body plus the length of the roll and cord, and as the opening is not of a very positive character the depth of the free fall may be considerably extended, beyond the initial depth, before the parachute opens.

Still another scheme is to project the parachute upwards, so that it is caught in the slip-stream, and that lifts the aviator out of the aeroplane. This upward discharge of a parachute may be accomplished by means of compressed air, or by aid of a spring or else of a pyrotechnical device.

Another important requirement in the case of the aeroplane parachute is the elimination of the difficulty of the entanglement of the rigging, which only too easily occurs when it is flogged together in an air current. This trouble, which seemed at first almost insuperable, has been completely overcome by Calthrop's discovery that tapes packed and folded so as to retain their obliquation are incapable of entanglement in the strongest current. In the instance of the Guardian Angel parachute these tapes are ingeniously retained in position upon the bottom metal disc cover by small rubber bands. The main tapes are extended by means of breaking pieces attached to the launching disc, and, during extension, develop a resistance which serves to retard the aviator's fall. When the main tapes are fully extended, then the breaking pieces snap dissynchronously, the doublet tapes are also freed, and the pull comes upon the silk body, which is straightway stripped from the launching disc, and leaves it behind. In short, this parachute is a machine, with its parts so designed that they can only act in ordered sequence and in predetermined paths. The release and action is completely and automatically actuated by the fall of the aviator. In operation this particular parachute extends in a concertina-like fashion. The aviator sits in his harness with the shock-absorber sling attached to the parachute. When trouble

occurs all he has to do is to dive overboard. The pull comes first on the shock-absorber, then the main supporting tapes unwrap in their controls, followed by the branch tapes. Finally, the pull comes upon the body—of fine silk—the snatch unfolds it from its carefully packed state, and brings it over the aluminium spreader disc. While the parachute is unfolding, it is protected from the effects of air pressure by another aluminium disc, which serves as a shield. Thus, there is no fear of entanglement; the whole operation of release from the disc, moreover, only takes the fractional part of a second. The full expansion of the parachute takes place in the air, the momentum is absorbed, and the man is falling at the safe landing speed of 15 ft. per second in the astonishingly short period of $2\frac{1}{2}$ seconds. All this takes place in a vertical fall of 100 ft. There is practically no free fall—so upsetting to the nerves—the aviator experiences no shock whatever; all that he feels is a quickly increasing support until he is fully supported by the air. In a new form of the Calthrop parachute, the body material passes over the edge of a ring suspended from a flexible container. This method very considerably reduces the weight, bulk, and cost, without in any way interfering with the positive opening action characteristic of the metallic disc.

In other systems which do not employ a launching disc, the procedure, when folding and packing up the parachute, is to lay out the rigging, so that each strand is straight and clear of all the others. Then the various cords are tied together with bits of sewing cotton, at suitable intervals, so that when stowed away into a compartment of a suitable bag (which may take the form of a haversack on the aviator's back), together with the rolled parachute (in another compartment of the container), to which it is attached, the liability of becoming entangled on launching will be obviated. From this description it might seem as if the packing up of a parachute was quite a simple matter. In practice, however, a good deal of experience is required.

The standard Guardian Angel parachute is 28 ft. in diameter, and the total weight, including the aviator's harness, attachments, aeroplane fittings, and release gear, etc., is about 36 lbs. It will support a load of 12 stones, and has already permitted of safe drops of men from aeroplanes in motion at speeds as high as 130 miles per hour. It is anticipated that the latter speed will shortly be increased to 150 miles per hour. If a parachute body is slightly damp, it will take slightly longer to open out fully, and make a longer drop before full expansion. Hence, special precautions must be taken to see that it is "stove" dry before it is packed away in its case.

Dynamometer trials indicate that the launching shock for a given parachute is not standard, but varies in accordance with (a) the method of packing adopted; (b) the launching system and degree of shock-absorption achieved by special appliances; (c) the disposition of the parachute on the aeroplane; (d) the load; and (e) the velocity and vertical angle of flight.

Harness.—Any harness designed for taking the weight of the body in a parachute descent, should be so arranged as to principally support those parts of the body most suitable for receiving shocks anatomically, i.e., in the case of rear suspension, the armpits and waist; in the instance of central suspension, the armpits and buttocks; and in the case of frontal suspension, the shoulders, buttocks, and thighs. In no case must any pressure occur in the fork.

To obviate the parachutist from being dragged along the ground after alighting, a quick harness release should be fitted. The harness may advantageously be adapted to also serve as a safety belt when the aviator is in the aeroplane.

Descent.—Owing to varying wind currents, eddies, bumps, etc., the body of a descending parachute is in a continuous state of slightly opening and closing, and the pressure underneath varies accordingly. Though this movement takes place in the body, the load (the passenger) descends steadily, for elastic shock absorbers and the giving way of the gussets take up all this motion.

It has been observed that the actual area of a parachute of, say, 28 ft. in diameter, when measured on the ground, is contracted to 21 ft. in diameter, when carrying a load in the air. However, this does not seem to affect the supporting capacity of the parachute. Mr E. R. Calthrop, who has devoted considerable time to a study of this peculiarity, has come to the conclusion that this reduction of area in the actual parachute body is counterbalanced by the effective resistance of an area of compressed air, which is escaping the whole time from the periphery of the parachute. This is indicated by the curved lines in the lower of the two diagrams on the opposite page to this. Also the effect of suction eddies on the upper surface of the parachute body has to be taken into consideration. This effect is likewise indicated in the second diagram.

The centre line of an aeroplane parachute, as it fully expands, oscillates through an arc of 90°, yet the swing is so quickly reduced, that when dropped from a height of 250 ft., no difficulty is experienced in landing.

The upper diagram demonstrates that when a parachute is swinging, the uppermost part of the rigging is in tension; this is owing to the fact that the underside of the body is always indented, as indicated by the dotted line.

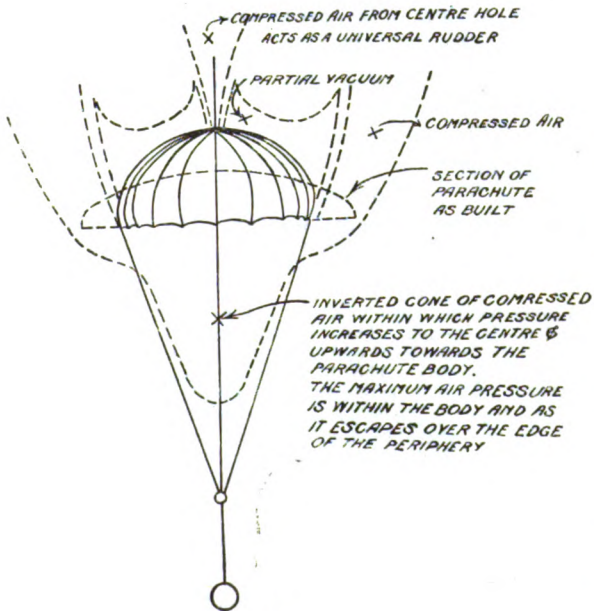
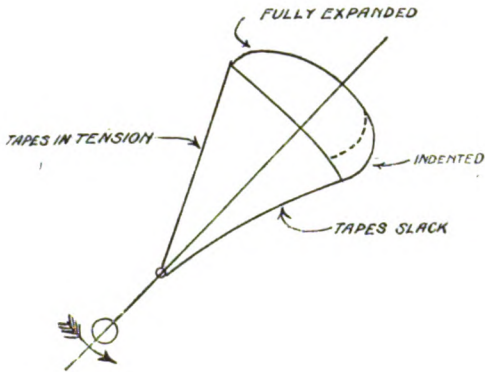
Once opened to its full extent, nearly every make of parachute is a perfectly safe vehicle for descent. It is in the preliminary opening that the risk lies, and the idea of the modern aeroplane parachute is to eliminate this risk.

The Fokker type parachute opens in a high wind in 3 to 3½ seconds, and under the same conditions the Spencer type parachute opens in 2 to 3 seconds. Other parachutes take as much as 4 to 5 seconds. Certain French parachutes have been tried which open in ½ to

E. R. Calthrop (Detachable Datas) System U.S. Patent applied for
R. Horlar McArthur Patents previously protected

PARACHUTES

629.13.6



1½ seconds; this rapid deployment, however, causes considerable shock, hence a longer period opening parachute is to be preferred.

The average rate of fall of a well-designed parachute is 1,000 ft. per minute, or 16·6 ft. per second (4 to 5 m. per second). This means an impact on landing, equivalent to a jump to the ground from an elevation of very slightly over 4 ft. It is advantageous to keep the air speed of descent as high as possible, but in no case should the descent be greater than the equivalent of a jump from over 10 ft. A descent velocity of 25 ft. per second must be regarded as a practical limit. Anything higher than this becomes dangerous.

Should it be desired to increase the speed of descent, for the purpose of getting clear of the aeroplane from which the launching took place; for stopping side-slipping or gliding; or for selecting the best possible landing place; a set of about four cords is sometimes attached to the periphery of the parachute so as to contract it, and consequently the area of the parachute when required. The path of the fall of a parachute from an aeroplane is parabolic. Owing to practical circumstances, such as varying wind currents, bumps, etc., the path can never, of course, be a true parabola.

SPEED AND EQUIVALENT IMPACTS

Feet per second	10	13	14	15	16	20	25	30	
„ minute	600	780	840	900	960	1,200	1,500	1,800	
Miles per hour	6·82	8·86	9·54	10·23	10·9	13·6	17	20·46	
Impact on landing equivalent to a jump to the ground from	ft.	2	2·9	3	3·5	4	6·2	9	14

Calculation of Average Velocity.—This is determined by dividing the altitude (A) by the time in seconds (T) required to fall. That is $V = \frac{A}{T}$.

A more useful figure, however, is the average velocity after the parachute is opened. This is determined by dividing the height at which the parachute opens by the time in seconds required to fall after opening. The height at which the parachute first commences to open is obtained by taking observations from the ground with an engineer's level, and calculated from the formula: $A = a \tan \theta$, where θ = angle of elevation, and a the distance from the engineer's level to the point where the parachute was dropped. The drift of the parachute can be determined by taking observations at two points and calculating the distance corresponding to the drift.

The velocity, upon striking the ground, is always slightly less than the average velocity of descent. The usual method for determining this factor, is to attach a cord of convenient length, say 20 yds. (or 20 m.), to the load. On the lower end of this cord,

a small sand-bag is fixed, and the time is observed between the striking on the ground by this sand-bag and by the load. Then :—

$$V = \frac{W}{Kr^2}$$

Where K is a function bending upon the angle of curvature, length of suspension, and kind of stuff of which the parachute is made. W = the weight of the sand-bag, and w = the weight of the parachute ; and r = the air resistance.

SOME LOW-LEVEL PARACHUTE RECORDS

(Guardian Angel Parachute)

Height in Ft.	Launched from	Speed, m.p.h.	Parachutist.	Date.
900	S.S. "Airship"	12-15	Sir B. Leighton	Aug. 1916
350	Kite balloon	60 (gale)		
600	Aeroplane	60	Capt. C. F. Collett	Jan '1917
153	Tower Bridge	...	Maj. T. Orde Lees	Nov. 1917
153	"	...	Lt. A. E. Bowen	"
400	Aeroplane	60	W. L. Wade	'18

The **efficiency** of the Spencer parachute in flight is approximately 70 per cent. As this is a good type, there is evidently considerable room for improvement in the design of all makes of parachute.

On an average, the fitting of the heavier types of parachute to an aeroplane reduces the rate of climb by 500 to 100 ft. per minute, and the speed by 2 or 3 miles per hour, *i.e.*, under circumstances where the weight of the parachute is already additional to the load carried on an aeroplane.

Descent Data.—The table herewith gives the descent data for a parachute 28 ft. in diameter. The figures for the 12-stone passenger have been checked by actual experiment. It will be noted that, of course, the lighter the parachute is, the less the impact on landing. If too light in weight, the parachutist may be put to some discomfort, owing to the swinging of the parachute that may take place, due to lack of sufficient load. One of the commonest causes of the heaviest swings of a parachute is due to local air eddies. These shift the body of the parachute away from above the centre of its load. Another equally common effect, which gives rise to similar excessive swinging, is due to the parachute dropping from a current of air travelling in one direction into a current travelling another way.

DESCENT DATA FOR PARACHUTE 28 FT. DIAMETER

[illegible]

DE-DA (Detachable Data) System
R. Barase Matheson Patents (provisionally protected). U.S. Patents applied for.

WIRELESS TELEGRAPHY

Most of the larger and more powerful aeroplanes and seaplanes are now equipped with wireless telegraphic apparatus. The necessary aerial or antenna usually consists of a trailing wire. Airships are similarly equipped. This method of signalling is, of course, much more effective than the dropping of smoke balls and tinsel, and other visual signals.

Anyone who has a knowledge of telegraphy, or in other words is well practised in transmitting by the Morse code, can easily operate a modern aircraft wireless set, for the operation is very simple. There are usually only two adjustments—the length of the trailing aerial and a handle to regulate the wave length. The only parts that require attention from time to time are the contact-breaker and sparking-points.

The trailing wire or antenna is about 250 ft. long, and is wound up, when not in use, on a geared wheel. The power for operation is obtained from batteries, which are charged, when not in use for wireless work, by fan-driven generators, mounted on the aeroplane, in the slipstream of the airscrew. The apparatus is preferably constructed with a quick wave changer for wave lengths of 90, 200, 300, 378, 476, 600, 756, and 952 metres, and should include a variometer for close tuning. The various portions of the equipment should be streamlined and proof against the action of salt water, spray, rain, or fog. All sparking points should be totally enclosed to avoid setting fire to any petrol vapour in the vicinity of the instrument. The weight of an ordinary wireless equipment for aeroplane purposes is about 80 lbs.—this weight must, of course, be provided for in the design of the machine. The United States Navy allows for a weight not exceeding 100 lbs.

Wireless Telegraph Transmitters

Marconi—				
Power, in watts	-	-	40	100
Range on land, in miles	-	-	15-20	25-35
Standard wave lengths, in metres	-	-	200-400	200-400
Battery voltage	-	-	8	16
Weights in lbs. :—				
Instrument box	-	-	12·5	20
Key	-	-	0·75	0·75
Battery	-	-	17	34
Dubilier, lbs.	-	-	30	40
Rouget, lbs.	-	-	...	70
Rouget, watts	-	-	...	100

Directions for Mixing Aircraft Glues*(Alfred Adams & Co. Ltd.)*

1. Break the glue into small pieces.
2. Take $1\frac{1}{2}$ pints of water to every pound of airscrew glue, or take 1 pint of water to every pound of other good quality glue.
3. Place the stated proportions of glue and water to steep in a clean vessel until the glue is uniformly soaked. During the process (which will take from 6 to 12 hours, according to the time of year) it is necessary to turn the glue over once in order to secure the uniform soaking of the glue.
4. When the glue is thoroughly soaked, heat the vessel in boiling water until the mixture becomes uniformly liquid and free from all lumps. In no case should it be necessary to heat the glue longer than one hour in order to secure this uniformly liquid mixture.
5. The vessel containing the liquid glue is then removed *at once* from the source of heat, placed on one side, and regarded as the stock glue mixture for the day's work.
6. Quantities of this stock mixture (either in liquid form when warm, or jelly form when cold) are transferred to clean glue pots for immediate use as required.
7. Sufficient glue should be soaked and prepared every day for the next day's work.
8. "Boiling" the glue does *not* improve the glue. The longer the glue is kept hot before use the more it loses in strength, though it may thicken, due to the evaporation of the water.

Directions for Glueing.—(a) Never use stale glue ; (b) all glue vessels must be kept perfectly clean ; (c) the faces of the wood to be joined together must be perfectly "true," after which they should be lightly "toothed" with a fine toothing plane ; (d) the surface of the wood should be hot before the glue is applied ; (e) apply the glue to both surfaces quickly and evenly, and see that the whole of both surfaces are thoroughly covered ; (f) the glueing room must be maintained at a temperature not below 70° F., and all draughts must be carefully avoided during the glueing operation.

*Pat. 2,014,101 (U.S. Patents applied for)
A. B. & C. Mather, Patents provisionally protected*

METALS

For Aircraft Construction

Most materials other than metal are not very satisfactory for aircraft construction, for they are not so permanent, and cannot so well withstand age, varying temperature, and humidity conditions. Neither can such accurate results be obtained by calculation in anticipation, as in the case of metals. As aircraft become larger and larger, more and more metal will undoubtedly enter into their construction, and, in fact, it is imperative that metal construction should be adopted in order to withstand the wear and tear of commercial service. This is anticipating, however, for at the moment non-metals hold sway.

Standard Specifications.—In the earlier days of aviation the only recognised specifications for the materials employed in the manufacture of aeroplane parts were those of official departments. The first of importance were issued by the Royal Aircraft Factory (R.A.F.), now called the Royal Aircraft Establishment (R.A.E.), to prevent confusion with the initials of the Royal Air Force. These specifications were, in due course, superseded by the Air Board (A.B.) specifications. In their turn, these last-named specifications are now in course of replacement by those of the British Engineering Standards Association (B.E.S.A.). On the committees of this Association are found representatives of official departments, aircraft manufacturers, and scientists. Hence, arbitrary biased specifications are avoided, and the results are satisfactory to all parties. All sources of friction in this direction are thus eliminated, and harmony and co-operation thereby attained.

The complete set of specifications that are already available, form a considerable bulk. As a general guide, a tabulated synopsis is given herewith of the principal specifications that affect aeroplane metal parts.

669.14

Steel.—The question of steel for aero work has received a great deal of attention. It is important that the steel used should be pure. Gen. Bagnall Wild recently stated five steels would cover 80 per cent. of the tonnage for aircraft work. The five varieties were:—

- 0.15 per cent. case hardening.
- 0.3 per cent. case hardening.
- 0.4 per cent. case hardening.
- 0.3 per cent. nickel steel; and
- 0.3 per cent. nickel chrome steel.

AIRCRAFT STEELS (Arranged in Order of Strengths)

Ultimate Strength.	Type.	Form.	Specifica- tion.	Yield Ratio or Point.	Elongation.	Reduction of Area.	Composition per Cent.						
							C.	Mn.	Si.	S.	P.	Ni.	Cr.
Tons per Sq. In.					Per Cent.	Per Cent.							
26	"20" car- bon	Bars	S. 21	50 per cent. Tons per Sq. In.	{ 20 bright 26 black	{ 40	.15-.25	4-.85	.25	.06	.06	...	...
35	Medium carbon	D r a w n bars	S. 1, pt. 1	25	15	40	...	...	...	.06	.06	...	...
		Hot-rolled bars	S. 1, pt. 2				...	...	...	.06	.06	...	...
		Forgings - Billets	S. 6 S. 23	20	20	40	.25-.4 .25-.4	4-.85 4-.85	.30 .30	.06 .06	.06 .06	...	...
40	Carbon	Forgings - Billets	S. 26 S. 27	60 per cent.	20	70	.3-.45	5-.8	.30	.06	.06	1	.5
45	3 per cent. nickel	Bars	S. 8	Tons per Sq. In.	24	50	...	...	...	.04	.04	2.5	...
		Forgings - Billets	S. 9 S. 10										
55	Alloyed	Bars	S. 2, S. 30	45	18	55	.28-.4 .28-.34	5-.8 4.5-.7	...	.04	.04	3.4 3.3.75	9.1.5 5.1
		Forgings - Billets	S. 11 S. 12				.28-.34	4.5-.7	...	.04	.04	3.3.75	5.1
60	"	Bars	S. 34	50	17	40	.32-.38	4.5-.7	...	.04	.04	3.3.75	5.1
		Forgings - ings, and finished parts	S. 33 S. 18, S. 28	120 D. ft. - lbs. 8 24	8 9	20 24	.4 .35	.7 .5	...	.04	.04	3.5.5 3.75.4.75	1.8 1.1.8

Note.—For case-hardening steels, see next page.

U.S. Patents applied for
K. Barlow Matthews. Patents (progressively protected). U.S. Patents applied for
P.E.D.A. (Detachable Data) System

AIRCRAFT CASE-HARDENING STEELS

Ultimate Strength.	Type.	Form.	Specifi- cation.	Yield Point.	Elonga- tion.	Reduc- tion of Area.	Composition per Cent.					
							C.	Mn.	S.	P.	Ni.	Cr.
Tons per Sq. In. 30	" 10 C "	Bars, forgings, and finished parts	S. 13	18	Per Cent. 25	55	.8-.14	.25-.6	.04	.04	...	...
38	" 15 C "	"	S. 14	25	20	55	.12-.2	.5-.1	.04	.04	...	...
45	3 per cent. nickel	"	S. 15	30	15	60	.1-.2	.25-.75	.04	.04	2-3-5	...
50	Nickel chrome	"	S. 16	120 D. 30 ft.-lbs.	17	35	.1-.2	.1	.04	.04	4	1-1
60	5 per cent. nickel	"	S. 17	27-5	13	40	.08-.14	.1-.4	.04	.04	4-5-6	.25

Note.—For standard steels, see previous page.

SPECIAL FORMS OF STEEL

Ultimate Strength.	Form.	Specifi- cation.	Yield Point.	Elongation.	Reduction of Area.	Composition per Cent.						
						C.	Mn.	Si.	S.	P.	Ni.	Cr.
Tons per Sq In.			Tons per Sq. In.		Per Cent.							
...	Sheets : Tinned -	S. 20	...	...	...	.13	.5	...	.07	.07	...	...
26	For welding -	S. 3	18	...	...	.25	.6	...	.04	.04	...	...
48	Nickel steel -	S. 4	34	...	...	.18-.24	.6	...	.04	.04	4-5.5	...
19	Castings : Semi-steel -	C.I.1,	...	.3 on 2 in.	...	...	...	...	...	...	...	...
		C.I.2	...	.45 "	...	...	...	...	...	...	...	...
40	Stainless valves -	S. 19	30	18 percent.	50	.2-.4	.5	.5	.06	.06	...	11-5.14
55	Key steel -	S. 24	28	15 "	45	.55-.8	.8	...	.04	.04	...	...
...	High carbon (tool steel)	S. 25	...	...	...	.8-1	.6	.1-.25	.035	.035	...	...
...	Wire for welding -	S. 32	...	...	...	.1	.6	.15	.04	.04	...	...
55	Wire for cold-headed bolts	W. 8	...	...	...	.42-.52	.5-.8	...	.04	.04	...	...

Non-Ferrous Metals

Aluminium Alloys.—The softness and weakness of pure aluminium has led to the introduction of many alloys in which aluminium, as a base, is combined with copper, nickel, zinc, or magnesium, or with more than one of these metals. A very complete series of tests on various alloys is now in progress at the National Physical Laboratory, and the final results when published should prove invaluable.

The following table gives the results of a series of experiments carried out by Dr Rosenhain at the Laboratory on four typical alloys, as compared with pure aluminium :—

Material.		Condition.	Ultimate Strength.	Elongation on 2 In.
	Per Cent.		Tons per Sq. In.	Per Cent.
Aluminium	- 100	Chill castings	5.2	37.0
		Hot-rolled	7.2	30.5
		Cold-drawn	8.7	19.5
Aluminium Copper	- 97.23 - 2.77	Chill castings	8.6	10.5
		Hot-rolled	16.6	16.0
		Cold-drawn	17.8	9.5
Aluminium Copper	- 96.24 - 3.76	Chill castings	9.6	10.5
		Hot-rolled	17.0	21.0
		Cold-drawn	20.0	17.5
Aluminium Copper	- 96.0 - 2.06	Chill castings	9.06	5.0
		Hot-rolled	17.04	16.0
Manganese	- 1.94	Cold-drawn	18.32	6.0
Aluminium Copper	- 96.17 - 2.89	Chill castings	12.05	13.5
		Hot-rolled	16.5	15.0
Manganese	- 0.94			

The modulus of elasticity of the alloys in the foregoing table is of the order of 10×10^6 lbs. per square inch, and the density approximately 2.7.

Magnalium is an alloy of aluminium and magnesium, the proportion of the latter varying from 3 to 10 per cent. Specific gravity, 2.5. Can be cast, welded, soldered, forged, etc.; is claimed to be twice to two and a half times as strong as aluminium. Rather expensive, but can be obtained in convenient form as sheet, from 0.1 to 5 mm. thickness; wire, from 0.1 to 10 mm. diameter; and tubing, 10 to 100 mm. diameter and 1 to 5 mm. thick; as well as castings and bars. Manufactured by the German Magnalium-Gesellschaft.

Duralumin contains over 90 per cent. of aluminium. Specific gravity, 2.85; melting point, 650° C. Properties vary with treatment: can be obtained with an ultimate tensile strength of 25 tons per square inch, and an extension of 15 per cent. in 2 in. Is unaffected by mercury, and can be obtained as plates, bars, sheets (above 0.05 in. thick), screws, forgings, stampings, tubes, or wire. Manufactured by the Electric and Ordnance Accessories Company.

Aluman contains 88 per cent. aluminium, 10 per cent. zinc, and 2 per cent. copper. Stated to be very strong, and can be readily forged and milled, but is rather heavy.

Macadamite is composed of 72 per cent. aluminium, 24 per cent. zinc, and 4 per cent. copper. Tensile strength stated as 20 tons per square inch, but probably is not ductile, and stands shocks badly. Specific gravity comparatively high.

Nickel-Aluminium.—This alloy is stated by its manufacturers to have an ultimate tensile strength, as castings, from 18,000 to 28,000 lbs.; as plates, from 35,000 to 50,000 lbs., with an extension of 10 per cent. on 2 in.; as bars, from 30,000 to 45,000 lbs. Manufactured by the Pittsburgh Reduction Company. Specific gravity, 2.9.

Argentium.—Specific gravity, about 2.9; contains antimony.

Chromaluminum is composed of aluminium, chromium, and other metals. Specific gravity, 2.9. Stated to be one of the strongest light alloys.

Wolframium, or Wolframinium, contains aluminium, 98.04 per cent.; antimony, 1.442 per cent.; copper, 0.357 per cent.; tungsten, 0.038 per cent.; and tin, 0.015 per cent. Density the same as pure aluminium (2.6). Readily worked. Tensile strength, hard drawn, 23 tons per square inch; annealed, 16 tons per square inch, with an extension of 15 to 24 per cent. in 2 in. This alloy has been used in the construction of the Zeppelin airships.

Clarus alloy.—Can be obtained as castings, tubes, sheet, or wire. Tensile strength, 17 tons per square inch in the form of tubes, or 40,000 lbs. per square inch in the form of wire. Manufactured by Gabriel & Co., Birmingham.

Partinium (Victoria Aluminium).—Composition varies, but contains small quantities of copper and zinc. Best qualities have a tensile strength of 16 tons per square inch, with an extension of 10 to 12 per cent. in 2 in. Casts well, and is used for crank cases, etc.

D.E.D.A. (Detachable Data) System
R. Borlase Matthews' Patent! (provisionally protected). U.S. Patents applied for.

AIRCRAFT BRASSES

AIRCRAFT BRASSES

669.71

Form.	Specifica- tion.	Ultimate Stress.		Yield Point.		Elonga- tion.		Reduc- tion of Area.		Copper.		Tin.		Zinc.		Lead.		Im- purities.	
		Tons per Sq. In.		Tons per Sq. In.		Per Cent.		Per Cent.		Per Cent.		Per Cent.		Per Cent.		Per Cent.			
Bar:																			
High tensile	B. 1	28		20		25		50		...		...		...		...		...	
Ordinary	B. 6	22		...		20		...		62		1		37		...		...	
High speed screwing	B. 13	20		8		12		...		58		...		40		2		...	
For brazing	B. 11	20		...		25		50		78.82		...		22.18		...		...	
Sheet:																			
Hard	B. 5	26		...		25		...		60		...		39		...		1	
Annealed	B. 12	18		...		35		...		60		...		39		...		1	
Bearings:																			
Gun-metal	B. 2	14		7.5		10		...		86		10-12		2.5		...		...	
Phosphor bronze	B. 8																		
White metal	L. 9																		
Castings:																			
Brass	B. 14	15		6		15		...		55		...		43		...		2	
Gun-metal (14 tons)	B. 2	14		7.5		10		...		86		10-12		2.5		...		...	

ALUMINIUM AND ALLOYS

	Official Specification.	Ultimate Stress.	Yield Point.	Elongation.	Reduction of Area.	Specific Gravity	Percentage Composition.						
							Aluminium.	Copper.	Zinc.	Lead.	Silicon.	Iron.	Tin.
Duralumin bar:													
Hammered above 2½ in. diameter	L. 1	17	10	15	20	2.85	...	...	...	...	...	...	...
Extruded up to 2½ in. diameter	L. 1	25	16	15	...	2.85	...	...	...	...	...	...	...
Duralumin sheets	L. 3	25	...	10-15	...	2.85	...	...	...	...	...	...	...
Aluminium sheets	L. 4	10	...	3	...	...	80.84	2.5.3	12-14.5	0.1	1	1	...
Aluminium alloy	L. 5	11	...	4	...	...	80.84	2.5.3	12-14.5	0.1	1	1	...
castings for general use													
12 per cent. copper-aluminium	L. 8	9	...	...	...	...	84.86	11.13	0.1	0.1	1	1	...
Copper-tin aluminium alloy	L. 10	9	...	...	...	...	86.88	9.11	...	0.1	1	1	0.5-1.5
7 : 1 aluminium alloy castings	L. 11	8	...	...	...	...	88.90	6.8	1	0.1	1	1	0.5-2
Half-hard aluminium sheets	L. 16	7.5	...	10	...	2.75	...	...	...	...	...	...	...
Soft aluminium sheets (annealed)	L. 17	5.5	...	15	...	2.75	...	...	...	...	...	...	...
Aluminium castings (ordinary)	L. 18	7	...	...	...	3.2	...	...	...	...	...	...	...

WEIGHTS OF METALS

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WEIGHTS OF STEEL BARS, ROUNDS, AND SQUARES, IN LBS. PER LINEAL FOOT

Diameter or Side in Inches.		Round.	Square.	Diameter or Side in Inches.		Round.	Square.
Fractions.	Decimals.	Lbs.	Lbs.	Fractions.	Decimals.	Lbs.	Lbs.
$\frac{1}{8}$	.1250	.0418	.0531	$1\frac{5}{16}$	1.1875	3.790	4.810
$\frac{3}{16}$	.1875	.0652	.0831	$1\frac{3}{4}$	1.2500	4.172	5.312
$\frac{1}{4}$	.2500	.0940	.1200	$1\frac{5}{8}$	1.3125	4.630	5.880
$\frac{5}{16}$	.3125	.1278	.1628	$1\frac{7}{8}$	1.3750	5.049	6.428
$\frac{3}{8}$	.3750	.1670	.2130	$1\frac{9}{16}$	1.4375	5.550	7.050
$\frac{7}{16}$	.4375	.2113	.2691	$1\frac{1}{2}$	1.5000	6.008	7.750
$\frac{1}{2}$	.5000	.2610	.3320	$1\frac{5}{8}$	1.5625	6.560	8.330
$\frac{9}{16}$	.5625	.3157	.4019	$1\frac{3}{4}$	1.6250	7.051	8.978
$\frac{5}{8}$	.6250	.3760	.4780	$1\frac{7}{8}$	1.6875	7.650	9.720
$\frac{3}{4}$	.7500	.4408	.5613	$1\frac{1}{2}$	1.7500	8.178	10.412
$\frac{7}{8}$	.8750	.5110	.6510	$1\frac{5}{8}$	1.8125	8.830	11.210
1	1.0000	.5871	.7474	$1\frac{3}{4}$	1.8750	9.388	11.953
$1\frac{1}{8}$	1.1250	.6680	.8490	$1\frac{7}{8}$	1.9375	10.090	12.810
$1\frac{1}{4}$	1.2500	.7562	1.076	2	2.0000	10.681	13.600
$1\frac{3}{8}$	1.3750	.8520	1.043	$2\frac{1}{8}$	2.1250	12.140	15.410
$1\frac{1}{2}$	1.5000	.9575	1.262	$2\frac{1}{4}$	2.2500	13.610	17.280
$1\frac{5}{8}$	1.6250	1.075	1.502	$2\frac{3}{8}$	2.3750	15.160	19.250
$1\frac{3}{4}$	1.7500	1.205	1.763	$2\frac{1}{2}$	2.5000	16.800	21.330
$1\frac{7}{8}$	1.8750	1.345	2.044	$2\frac{5}{8}$	2.6250	18.522	23.520
2	2.0000	1.495	2.347	$2\frac{3}{4}$	2.7500	20.330	25.810
$2\frac{1}{8}$	2.1250	1.655	2.670	$2\frac{7}{8}$	2.8750	22.220	28.210
$2\frac{1}{4}$	2.2500	1.825	3.030	3	3.0000	24.190	30.720
$2\frac{3}{8}$	2.3750	2.005	3.403	$3\frac{1}{4}$	3.2500	28.390	36.050

WEIGHTS OF HEXAGON STEEL BAR IN LBS. PER FOOT RUN

Width Across Flats	.280	.338	.445	.525	.600	.710	.820	.920
Weight per Foot Run, Lbs.	.231	.337	.589	.812	1.06	1.485	1.98	2.49
Width Across Flats	1.010	1.200	1.390	1.480	...	...	...	...
Weight per Foot Run, Lbs.	3.05	4.25	5.72	6.46	...	...	...	...

WEIGHT OF FLAT BAR IRON (Lbs. per Foot Run)

Width in In.	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	1 $\frac{1}{8}$	1 $\frac{1}{4}$	1 $\frac{3}{8}$	1 $\frac{1}{2}$	1 $\frac{5}{8}$	1 $\frac{3}{4}$	2
Thickness.												
$\frac{1}{4}$ in.	.42	0.53	0.63	0.74	0.84	0.95	1.05	1.16	1.26	1.37	1.48	1.69
$\frac{5}{16}$ "	.53	0.66	0.79	0.93	1.05	1.18	1.32	1.45	1.58	1.71	1.85	2.11
$\frac{3}{8}$ "	.63	0.79	0.95	1.11	1.26	1.42	1.58	1.74	1.90	2.06	2.22	2.53
$\frac{7}{16}$ "	.74	0.93	1.11	1.30	1.48	1.66	1.85	2.03	2.22	2.40	2.59	2.96
$\frac{1}{2}$ "	.85	1.06	1.27	1.48	1.69	1.90	2.11	2.32	2.53	2.74	2.95	3.38

WEIGHT OF METAL IN LBS. PER SQUARE INCH

THICKNESS IN STANDARD WIRE GAUGE

S. W. G. of Sheet.	Thickness in Inches.	Mild Steel.	Aluminium.	Brass.	Copper.	Duralumin.
6	0.192	0.054	0.0186	0.059	0.061	0.0197
7	0.176	0.050	0.017	0.054	0.056	0.0181
8	0.160	0.045	0.015	0.049	0.051	0.0164
9	0.144	0.040	0.014	0.044	0.046	0.0148
10	0.128	0.036	0.013	0.039	0.041	0.0132
11	0.116	0.032	0.011	0.035	0.037	0.01192
12	0.104	0.029	0.0101	0.032	0.033	0.0107
13	0.092	0.026	0.009	0.028	0.029	0.0094
14	0.080	0.023	0.008	0.025	0.025	0.0082
15	0.072	0.0202	0.0073	0.0218	0.023	0.0074
16	0.064	0.018	0.006	0.020	0.021	0.0065
17	0.056	0.0158	0.0056	0.017	0.018	0.0057
18	0.048	0.014	0.0047	0.015	0.015	0.0049
20	0.036	0.010	0.0036	0.011	0.012	0.0037
22	0.028	0.008	0.0028	0.0085	0.009	0.0028
24	0.022	0.006	0.0022	0.0067	0.007	0.0022
26	0.018	0.005	0.0018	0.0055	0.0057	0.0018
28	0.014	0.004	0.0014	0.0043	0.0045	0.0014
30	0.012	0.0034	0.0012	0.0037	0.0038	0.00123
32	0.010	0.0028	0.001	0.0034	0.0032	0.00102
34	0.009	0.0025	0.0009	0.0027	0.0029	0.00092
36	0.007	0.002	0.0007	0.0021	0.0022	0.00072
38	0.006	0.0017	0.0006	0.0018	0.0019	0.00061
40	0.004	0.0011	0.0004	0.0012	0.0013	0.00041

WEIGHTS OF METALS

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WEIGHTS OF METAL SHEETS IN LBS. PER SQUARE FOOT

Thickness in Standard Wire Gauge.	Thickness in Inches.	Aluminium.	Brass.	Copper.	Duralumin.	Steel.	Tin.
6	.192	2.65	8.54	8.76	2.80	7.68	7.37
7	.176	2.43	7.83	8.03	2.57	7.05	6.76
8	.160	2.21	7.12	7.30	2.33	6.40	6.15
9	.144	1.99	6.41	6.57	2.10	5.76	5.53
10	.128	1.77	5.69	5.84	1.86	5.12	4.92
11	.116	1.60	5.16	5.29	1.69	4.64	4.46
12	.104	1.44	4.63	4.75	1.51	4.16	3.99
13	.092	1.27	4.09	4.20	1.34	3.68	3.53
14	.080	1.10	3.56	3.65	1.16	3.20	3.07
15	.072	0.995	3.20	3.29	1.05	2.88	2.77
16	.064	0.885	2.85	2.92	0.934	2.56	2.46
17	.056	0.774	2.49	2.56	0.817	2.24	2.15
18	.048	0.663	2.13	2.19	0.700	1.92	1.84
19	.040	0.552	1.78	1.83	0.584	1.60	1.54
20	.036	0.497	1.60	1.65	0.525	1.44	1.38
21	.032	0.442	1.42	1.46	0.467	1.28	1.23
22	.028	0.387	1.25	1.28	0.408	1.12	1.08

Elimination of Gauge Numbers.—The American S.A.E. have decided that in future sheet metal is to be specified by thickness in decimal fractions of an inch. Rods, wires, and cables are to be specified by diameter in decimal fractions of an inch. Tubes are to be specified by outside diameter in inches or fractions, and thickness of wall in decimal fractions of an inch.

WEIGHTS OF METAL SHEETS

Size.		Thickness.		Weight : Lbs. per Square Foot.			Size.		Thickness.		Weight : Lbs. per Square Foot.		
S.W.G.	Birmg. Sheet Gauge.	Inch.	Mm.	Alum- inium.	Brass.	Copper.	S.W.G.	Birmg. Sheet Gauge.	Inch.	Mm.	Alum- inium.	Brass.	Copper.
		.375	9.525	5.18	16.7	17.1	7		.176	4.470	2.43	7.83	8.03
3/0		.372	9.449	5.14	16.5	17.0		31	.166	4.216	2.29	7.38	7.58
2/0		.348	8.839	4.81	15.5	15.9	8		.160	4.064	2.21	7.12	7.30
1/0		.324	8.229	4.48	14.4	14.8		30	.150	3.810	2.07	6.67	6.85
		.312	7.937	4.31	13.9	14.2	9		.144	3.658	1.99	6.41	6.57
1	40	.300	7.620	4.15	13.3	13.7		29	.136	3.454	1.88	6.05	6.20
		.289	7.341	3.99	12.9	13.2	10		.128	3.251	1.77	5.69	5.84
2	38	.278	7.061	3.84	12.4	12.7		28	.125	3.175	1.73	5.56	5.70
		.276	7.010	3.81	12.3	12.6	11		.124	3.150	1.71	5.52	5.66
3	37	.270	6.858	3.73	12.0	12.3		27	.116	2.946	1.60	5.16	5.29
		.252	6.401	3.48	11.2	11.5	12		.112	2.845	1.55	4.98	5.11
4	36	.250	6.350	3.45	11.1	11.4		26	.104	2.642	1.44	4.63	4.75
		.238	6.045	3.29	10.6	10.9	13		.100	2.540	1.38	4.45	4.57
5	35	.232	5.893	3.20	10.3	10.6		25	.092	2.337	1.27	4.09	4.20
		.216	5.486	2.98	9.61	9.86	14		.090	2.286	1.24	4.00	4.11
6	34	.212	5.385	2.93	9.43	9.68		24	.082	2.082	1.13	3.65	3.75
		.200	5.080	2.76	8.90	9.12	15		.080	2.032	1.11	3.56	3.65
	33	.192	4.877	2.65	8.54	8.76		23	.077	1.956	1.07	3.43	3.52
		.187	4.762	2.58	8.32	8.53	16		.072	1.829	.995	3.20	3.29
	32	.182	4.623	2.52	8.10	8.31		22	.072	1.829	.995	3.20	3.29
								21	.068	1.727	.940	3.02	3.11

WEIGHTS OF METAL SHEETS—Continued

WEIGHTS OF METALS

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Size.		Thickness.		Weight : Lbs. per Square Foot.			Size.		Thickness.		Weight : Lbs. per Square Foot.				
S.W.G.	Birmg. Sheet Gauge.	Inch.	Mm.	Alum-inium.	Brass.	Copper.	Steel.	S.W.G.	Birmg. Sheet Gauge.	Inch.	Mm.	Alum-inium.	Brass.	Copper.	Steel.
16	20	0.065	1.651	898	2.89	2.97	2.60	24	9	.023	.584	.318	1.02	1.05	.920
	19	0.064	1.626	885	2.85	2.92	2.56		8	.022	.559	.304	.979	1.01	.880
		0.063	1.600	870	2.80	2.88	2.52			.021	.533	.290	.935	.960	.840
		0.062	1.587	857	2.76	2.83	2.48	25	7	.020	.508	.276	.890	.914	.800
17	18	0.060	1.524	829	2.67	2.74	2.40			.019	.483	.262	.846	.868	.760
		0.056	1.422	774	2.49	2.56	2.24	26		.018	.457	.249	.801	.823	.720
	17	0.055	1.397	760	2.45	2.51	2.20	27	6	.016	.406	.227	.730	.750	.656
	16	0.051	1.285	705	2.27	2.33	2.04			.0160	.397	.215	.712	.731	.640
18	15	0.048	1.219	663	2.13	2.19	1.92	28		.0156	.397	.215	.694	.713	.624
		0.047	1.194	649	2.09	2.15	1.88		5	.0148	.376	.204	.638	.677	.592
	14	0.042	1.067	580	1.87	1.92	1.68			.0140	.356	.193	.623	.640	.560
19	16	0.040	1.016	552	1.78	1.83	1.60	29		.0136	.345	.188	.605	.622	.544
		0.038	.965	525	1.69	1.74	1.52	30		.0124	.315	.171	.552	.568	.496
20	13	0.036	.914	497	1.60	1.65	1.44		4	.0120	.305	.166	.534	.548	.480
		0.035	.889	484	1.56	1.60	1.40		3	.0105	.267	.145	.467	.480	.420
21	12	0.032	.813	442	1.42	1.46	1.28		2	.0090	.229	.125	.400	.412	.360
22	11	0.031	.793	429	1.38	1.42	1.24		1	.008	.203	.111	.356	.366	.328
		0.028	.711	387	1.25	1.28	1.12								
	10	0.027	.686	373	1.20	1.24	1.08								
23		0.024	.610	332	1.07	1.10	.960								

Specific Gravity -
Ratio of Weights -

8.42 8.82 7.74
3.23 3.30 2.90

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DE-DA (Detachable Data) System
R. Borlase Matthews' Patents (provisionally protected). U.S. Patents applied for.

TIMBER FOR AIRCRAFT CONSTRUCTION

TIMBER is not, strictly speaking, a material, but rather an elaborately formed structure composed of wood-substance, with cavities containing water and air. As the specific gravity of the wood-substance of all timbers is approximately constant (1.55 to 1.56), it follows that the specific gravity or weight per cubic foot of absolutely dry timber is an indication of the amount of wood-substance it contains. From this it will be appreciated that a heavy timber has considerable wood-substance, while a light timber has comparatively a small quantity, hence the hardness, heating power, stiffness, and strength of timbers are proportional to their specific gravity, provided they contain the same percentage of water.

Timber is affected, as regards its strength, by various circumstances, such as conditions under which the tree is grown (more especially as regards soil, climate, and light), the method of seasoning, and the portion of the tree from which the specimen is cut.

One and the same piece of timber varies greatly in strength, according to the direction, in regard to the grain in which the stress is applied. It is strongest when this is applied parallel to the grain, and weakest when the stress is applied transverse to the grain; when the stress is applied at intermediate directions the strengths vary in a corresponding manner. It is, therefore, important that wood should be straight-grained (not cross-grained, oblique-grained, or spiral-grained), and that pieces shall be cut parallel to the grain. Wood is stronger in tension than in compression, yet, when compared with metal for the same weight, wood is much stronger in compression, but weaker in tension.

Artificial seasoning is now very largely and successfully employed; the process, however, requires care and attention, especially in the case of woods whose mechanical properties must be preserved. The process is practically a properly regulated and uniform system for extracting the moisture from the wood; the result on the wood, however, is not merely extraction of moisture.

There is quite a considerable difference in each individual piece of timber, in the specific gravity and the compressive strength of the heaviest and lightest parts of its wood, *e.g.*, in the instance of the most important of all coniferous timbers, the Scotch pine, this may vary as much as 3 to 1. The effect of a colder climate is that the growth is slower and the annual growth-rings are narrower.

This diminution of the thickness of the rings generally takes place more at the expense of the soft, light, spring wood than of the harder, heavier summer (autumn) wood. Hence the narrower-ringed wood is generally heavier and stronger. Under conditions of severe ("sub-arctic") cold, the attenuation of the growth-rings continues, but the wood is lighter in weight, and weaker. An illustration of such wood is the red deal obtained from the North of Russia. Just as changes of climate affect the wood, so variations in the soil, and in the light to which the tree is exposed, cause corresponding changes in its structure and properties. As an illustration, it may be mentioned that in the Highlands of Scotland a slow-grown light Scotch pine is obtainable, which is eminently suitable for aeroplane construction.

In the instance of such hardwoods as the oak and the ash, which show a porous ring of spring wood, when the annual rings are wider because the growth is more rapid, the increased width of ring is chiefly caused by disproportionate additions to the heavy fibrous summer wood, produced outside the soft, weak, porous spring wood. The weakness of narrow-ringed, porous ash-timber is familiar to all practical men, especially in connection with those trees which have grown slowly under the influence of excessive shade. There is a decline in weight and strength in timbers of this type when the annual rings are of the same thickness, but there is a wider zone of porous wood (due to a larger number of series of pores).

The tendency for opposite effects to be induced in pine and ash timbers, by the widening or the narrowing of the annual rings, explains one practical matter in connection with parts of aeroplanes, in which the wood is used in the form of thin laminae, or is spindled; the pine must not be wide-ringed, whereas the ash must not be narrow-ringed.

The following table shows clearly values in specific gravity and compression parallel to the grain in proportion as the width of the annual rings increase:—

DE-DA (Detachable Data) System
R. Borlase Matthews' Patents (provisionally protected). U.S. Patents applied for.

NORWAY SPRUCE (*PICEA EXCELSA*) GROWN IN AUSTRIA

(Professor Janka)

Width of Annual Ring (in Millimetres).	Specific Gravity ($\times 100$).		Compression Parallel to the Grain (Crushing Stress in Kilograms per Square Centimetre).	
	Seasoned.	Absolutely Dry.	Seasoned.	Absolutely Dry.
0.5-1	44.9	41.7	397	743
1-1.5	44.3	41.3	395	729
1.5-2	43.1	40.2	386	708
2-2.5	41.9	38.9	364	666
2.5-3	41.3	38.4	353	647
3-3.5	39.9	37	339	622
3.5-4	40.2	37.2	342	619
4-4.5	39.1	36	314	581
4.5-5	40.2	36.8	308	554
Above 5	38.1	34.9	306	510

The principal timbers employed in aeroplane construction are ash and certain softwoods, including spruces (*Picea*), certain pines (*Pinus*), etc.; American canary wood and poplar are used in the construction of three-ply wood. Hickory is sometimes used for bent parts; while walnut and mahogany are utilised in the construction of airscrews.

Ash is tough (i.e., can be deformed considerably up to a relatively high elastic limit), it is suitable for members requiring great strength or subject to sudden shock. It must be straight-grained, free from all objectionable defects, preferably felled between the months of November and January (inclusive), and thoroughly seasoned (preferably naturally seasoned); for parts bent to shape under steam heat, ash should not have been felled more than eighteen months. The bending of ash should not be carried out in steam heat at a temperature exceeding 212° C.

Spruce [silver (*Sitka*), black, and white Canadian] is very largely utilised in aeroplane construction; it is light and strong for its weight, works easily, and is obtainable in uniform quality. The ends of spruce members should be protected, as this class of wood splits easily. The silver spruce from British Columbia is considered to be the best of its kind. Spruce should be free from cross shakes,

dote, deleterious resin pockets, and other faults. It should be preferably rift sawn (i.e., radially sawn), and have edge-grain. Properly seasoned spruce, if allowed to stand in the workshops for ten days or so after milling, can be drilled to jig without fear of holes going out of alignment, due to further shrinkage. It is very important in the manufacture of erection jigs to make provision for proper cramping arrangements. The reason for this is, that where the cross-sawn end of a member butts on to a longitudinal member, the crushed fibres due to the sawing need to be well compressed in position, or else the aeroplane, after its first rough landing, will require careful re-alignment.

European spruce warps and shrinks comparatively slightly.

The weight of spruce should not exceed 35 lbs. per cubic foot, when it contains 15 per cent. of moisture.

For testing purposes, cylindrical test pieces are prepared, each 3 in. long, with a diameter of $1\frac{1}{2}$ in. at the ends, and tapering to 1 per cent. in the middle, where for a distance of three-quarters of an inch the sample is made parallel. In compression, such samples should give an ultimate strength of not less than 5,000 lbs. per square inch, when the load is applied at the rate of between 3,000 and 6,000 lbs. per minute. If the ultimate strength is under 5,000 lbs., but over 4,000 lbs. per square inch, the timber could still be employed for less important parts. It is important that the timber should be tested for moisture; every foot contains 15 per cent. The specific strength is reduced by 230 lbs. per square inch for every 1 per cent. increase of moisture above 15 per cent., and *vice versa*. A bending test should also be carried out. For this purpose, test pieces should be prepared, 40 in. long, by 2 in. square, or 2 in. by 1 in., cut parallel to the grain. These samples are tested by loading so as to produce a pure bending moment in shear in the middle part, which does not exceed 70 per cent. of the elastic limit of the beam. From the measurement of the deflection, Young's modulus is calculated. For the highest grade timber this should not be less than 1,600,000 lbs. per square inch, and for second grade timber it must exceed 1,200,000 lbs. per square inch.

Another method of testing is known as the "four-point load." This was devised so that there may be no shearing stress in the middle part of the beam, when the deflection is measured (see diagram). The deflection is measured on a length l in the central part of the test piece (this measurement is usually made by the aid of a special deflection meter). Where W is the load, h the breadth of the sample, d the depth of the sample, and a the distance between the load points (see diagram). The required values are given by the equations:—

$$E = \frac{W a^3}{16 I d}$$

$$I = \frac{b h^3}{12}$$

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In addition to the above tests, specimens of about 4 to 6 in. in length should be split in two places approximately at right angles to each other; the exposed surfaces will thus indicate the true direction of the grain, which should not be inclined to the length of the piece of timber by more than 1 in 20.

True Poplars (*Populus*) vary considerably in their mechanical qualities. The wood is invariably uniform in texture, and in the better qualities, e.g., Italian black poplar is tough and strong in comparison with its weight. In contradistinction to the spruces, poplars are liable to shrink and warp. American or yellow poplar is known in England as white canary wood, and also as the timber of the tulip tree (*Liriodendron*); it is often used in the manufacture of three-ply wood. It is a light wood of very uniform structure, and is often used as a partial substitute for silver spruce. The true poplars have a very uniform texture; they take glue very well, as the adhesion is practically constant all over the surface.

Walnut is a wood of moderate weight. When once fully seasoned it stands out pre-eminently among other woods, as it does not shrink or warp, hence it is an ideal wood for the manufacture of airscrews, gun stocks, etc. In the transition from the green to the fully-seasoned condition, walnut shrinks to a very great extent, hence it is important to ascertain that the condition of full seasoning is attained before this wood is worked up.

Mahogany.—The Central American variety is easily worked up, but is rather liable to split. The Spanish (Cuba and the Islands) variety is stronger, but heavier than the Honduras; neither stands exceptionally well for its weight. Mahogany is generally singularly strong, and has likewise excellent mechanical qualities for its weight; it has a very small shrinkage from its green stage to its seasoned condition. It takes glue admirably.

African mahogany and a number of different kinds of similar wood of very little merit are also imported; of those which deserve to be named perhaps the best and most reliable stocks are those coming from Lagos, Benin, and Grand Bassam. This type of mahogany (*Khaya* spp.) contrasts with the American mahogany, in that the grain of the wood is more markedly interlocking; this is due to the fact that the successive layers of fibres run in alternation in right and left-hand spirals; the outcome of this is, that this particular wood, though proportionately not so strong, is less liable to split.

Three-ply Woods are largely used in aeroplane construction chiefly for main and tail planes, rib webs, and for covering the sides and other parts of the fuselage. In many modern aeroplanes it is utilised in parts under stress, for replacing bracing wires. The outer plies are usually of ash or birch, and the inner plies generally likewise; though for the latter, however, true poplar, American canary white wood, etc., are often substituted. It

PROPERTIES OF WOODS USED IN AIRCRAFT CONSTRUCTION

(Compiled by the Forests Products Laboratory, Madison, Wisconsin)

AVERAGE STRENGTH VALUES AT 15 PER CENT. MOISTURE

	Spruce, Red, White, Sitka. (<i>Picea rubens</i> , <i>canadensis</i> , <i>sitchensis</i> .)	Pine, Western Yellow or Calif. White Pine. (<i>Pinus ponderosa</i> .)	Pine, Sugar. (<i>Pinus Lambertiana</i> .)	Fir, Douglas. (<i>Pseudotsuga Douglasii</i> .)
Specific gravity based on volume and weight when oven-dry:				
Average -	41	42	39	52
Minimum -	36	38	36	47
Weight at 15 per cent. moisture:				
Lbs. per cub. foot	27	28	27	34
Shrinkage from green to oven-dry condition:				
Radial -	3.9	3.9	2.9	5.0
Tangential -	7.5	6.4	5.6	7.9
Static bending:				
Fibre stress of elastic limit—				
Lbs. per sq. inch	5,100	6,800	5,300	6,800
Modulus of rup- ture:				
Lbs. per sq. inch	7,900	8,700	7,400	9,700
Modulus of elas- ticity:				
1,000 lbs. per sq. inch	1,300	1,300	1,100	1,780
Work to maximum load:				
Inch-lbs. per cub. inch	7.4	6.7	5.0	7.2

PROPERTIES OF WOODS USED IN AIRCRAFT
CONSTRUCTION—*Continued*

(Compiled by the Forests Products Laboratory, Madison, Wisconsin)

AVERAGE STRENGTH VALUES AT 15 PER CENT. MOISTURE

	Spruce, Red, White, Sitka. (<i>Picea rubens</i> , <i>canadensis</i> , <i>sitchensis</i> .)	Pine, Western Yellow or Calif. White Pine. (<i>Pinus ponderosa</i> .)	Pine, Sugar. (<i>Pinus</i> <i>Lambertiana</i> .)	Fir, Douglas. (<i>Pseudotsuga</i> <i>Douglasii</i> .)
Compression parallel to grain : Max. crushing strength— Lbs. per sq. inch	4,300	5,000	4,300	6,000
Compression perpendicular to grain : Fibre stress at elastic limit— Lbs. per sq. inch	500	640	540	750
Shearing strength parallel to grain : Lbs. per sq. inch	920	1,040	950	1,020
Hardness side : Load required to imbed 0.444 inch ball one-half its diameter— Lbs.	430	430	410	580

STRENGTH AND WEIGHT OF TIMBER (Note.—"Transverse strength" = $\frac{\text{Modulus of rupture}}{8}$)

	Specific Gravity.	Weight of a Cubic Foot.		Weight of a Cubic Inch.		Tensile Strength per Square Inch.		Crushing Weight per Square Inch.		Transverse Strength.	
		Lbs.	Cubic Foot.	Lb.	Cubic Inch.	Lbs.	Cubic Inch.	Lbs.	Cubic Inch.	Lbs.	Cubic Inch.
Acacia, from to	.71	44		.025		16,000		...		1,867	
" Alder	.79	49		.028		...		...		...	
Ash	.80	50		.029		9,500		6,700		2,000	
"	.69	43		.025		12,000		8,600		3,000	
"	.76	47		.027		17,000		9,300		...	
Bamboo	.40	25		.015		39,000		...		...	
Beech, from	.69	43		.025		11,000		7,700		1,500	
" to	.696	43		.025		12,000		9,300		2,000	
Birch	.711	44		.026		15,000		3,300		1,900	
"	.730	45		.026		...		6,000		1,930	
Box	.45	80		.046		20,000		10,300		2,445	
Cedar, West Indian	1.28	47		.026		5,000		5,700		1,443	
" American	.748	35		.020		...		...		766	
" Lebanon	.554	30		.017		11,000		5,800		1,300	
Chestnut	.486	38		.022		12,000		4,500		1,770	
Cork	.606	15		.008		...		...		...	
Elm, English	.240	34		.02		13,200		10,300		782	
" "	.553	36		.021		14,000		...		...	
" Canadian	.579	45		.026		...		...		1,100	
Fir, Larch	.725	34		.019		8,900		...		1,920	
"	.543	35		.02		10,200		3,200		1,330	
" American white spruce	.556	34		.019		10,000		5,500		1,660	
" California spruce	.543	30		.017		12,000-14,000		8,500		...	
" Norway spruce	.486	32		.018		5,000-12,500		8,800		...	
" Riga	.508	47		.027		9,500		...		...	
" Memel	.753	34		.019		9,500		...		...	
" Scotch	.546	33		.018		...		...		...	
"	.528					7,100		...		...	

AIRCRAFT TIMBER

674

Fir, Christiania deal-	580	37	-021	12,400	5,800	...
Hickory	690	43	-025	12,000	9,000	2,400
Hornbeam	76	47	-027	20,000	4,600	...
Ironwood	115	71	-041	...	...	3,000
Jackwood	67	42	-024	...	...	1,830
Lancewood	725	45	-028	12,000	...	...
Lime-	564	35	-02	...	...	...
Lignum vitae	65 to 1-333	41 to 83	-024 to -049	12,000	9,000	2,000
Mahogany, Nassau	668	42	-024	...	...	1,719
" Honduras	560	35	-02	21,000	8,000	1,910
" Spanish	852	53	-031	12,000	8,200	1,300
Maple	675	42	-025	10,600	...	1,694
Oak, African	988	62	-035	17,000	...	2,523
" American, red	85	53	-03	10,000	6,000	1,680
" " white	779	49	-028	10,000	...	...
" English	777	48	-028	10,000	6,400	1,600
" " "	934	58	-034	19,000	10,000	1,690
Pine, red	576	36	-021	12,000	5,400	1,200
" " "	657	41	-024	14,000	7,500	1,530
" " white	432	27	-015	...	...	1,229
" " "	553	34	-02	...	...	...
" Georgia yellow	508	32	-018	20,000	5,300	1,185
" Dantzic	649	40	-023	8,000	5,400	1,426
" Memel	550	34	-02	...	...	...
" " "	601	37	-021	...	...	...
" Riga	466	29	-017	...	...	...
" Pitch	654	41	-023	12,000	...	1,383
Poplar	39	24	-014	6,500	7,500	1,600
Teak	74	46	-026	8,000	12,000	2,110
" " "	86	54	-031	15,000	...	...
Sycamore	604	38	-022	13,000	...	1,500
Walnut	671	42	-024	9,000	9,000	1,600

should be remarked that the texture should be as uniform as possible, so as to take the glue. The hardwood in ash timber does not readily take glue. The inner ply is usually between two-fifths and three-fifths of the thickness of the whole. The three layers of wood are glued together with the grain of the outer plies running lengthwise, while the centre ply is placed at right angles to them.

Considerable experience is required in the manufacture of good ply wood, both as regards the selection of the material and the actual process of making.

Ply wood is tested by placing small samples, about 2 in. square, in a dry oven at a temperature of 105° C. for a period of ten hours. The loss of weight, due to this treatment, should not exceed 15 per cent. of the original weight of the test piece. The next trial is usually a sure test of the cement joints; for this purpose 3 test pieces, 6 in. by 1 in. wide, are used. Two saw cuts are made in the middle of the test piece, 1 in. apart; these saw cuts are made from alternate sides through two plies. The breaking stress of at least two of the specimens should not be less than 150 lbs. per square inch. The load, of course, should be applied uniformly and steadily.

The next examination of the samples is by immersion of a piece about 6 in. $\times$ 6 in. in water, at a temperature of 45° C. The time of this steeping is three hours for plies under one-thirtieth of an inch, and six hours for heavier plies; at the end of this test the plies must not show any visible signs of separation at the edges. In the case of ply woods which are under one-eighth of an inch in thickness, a bending test is carried out on a sample 12 in. long, by 2 in. in breadth, so selected that the length of the strip rests across the grain of the outer plies. This test piece is then bent on a former, having a radius of 9 in. The strip is reversed to bend the other way on the former; under this condition there must be no sign of crack, fracture, or splitting of any kind.

Standard.—Wood is usually sold by the standard of 165 ft. cube. As an illustration, 120 pieces of 12 ft. $\times$ 11 in. $\times$ 1½ in. makes up one standard.

Note.—The standard varies in different parts of the world.

*DE. 44 (Detachable Data System)
R. B. W. Matthews. Patents (provisionally protected) U.S. Patents applied for.*

Leather Belting.—This should withstand a load of 5,000 lbs. per square inch. It must be free from flaws, warble holes, and other defects. It should be stitched with black hemp thread, previously served with preservative. All leather straps, etc., should, when in use, have periodical dressings of neat's-foot oil or other suitable stuff.

KNOTS

677-7

The knots shown on the following pages are used as follows :—

To make a knot on a rope.—Thumb knot, figure-of-eight knot.

To make a non-slipping loop on the end of a rope.—Bowline.

To make a non-slipping loop in the middle of a rope.—Bowline on bight.

To make a slip knot.—Hangman's knot.

To join two ropes.—Same sized ropes—Reef knot, hawser bend. Different sized ropes—Single-sheet bend. Wet ropes—Double-sheet bend.

To secure a rope to a spar.—Clove hitch, round turn and two half hitches, two half hitches, timber hitch, half hitch, fisherman's bend.

To secure a rope rapidly to a hook.—Blackwall hitch.

To secure a hook to the middle of a rope.—Catspaw.

To secure a spar across a rope.—Lever hitch.

To make a loop on a drag-rope.—Man's harness hitch.

To fix a rope "endways on" to a spar.—Timber hitch and half hitch.

To fix a rope "endways on" to a larger rope.—Rolling hitch.

677-71

Hemp Cord.—Official specifications call for the use of the finest Italian hemp. The cord is to be supplied in hanks of 60 yds.

TENSILE STRENGTH OF CORD

Size.	Strength.	Size.	Strength.
2 lbs. hank	400 lbs.	$\frac{3}{4}$ lb. hank	175 lbs.
$1\frac{1}{2}$ " "	310 "	$\frac{1}{2}$ " "	130 "
$1\frac{1}{4}$ " "	265 "	$\frac{1}{4}$ " "	75 "
1 " "	220 "	$\frac{1}{8}$ " "	45 "

When testing the above cords, the load is to be applied at the rate of 600 lbs. per minute, on a test piece 32 in. long.

USEFUL KNOTS

677-7



Thumb



Figure of 8



Reef



Single Sheet Bend



Double Sheet Bend



Hawser Bend



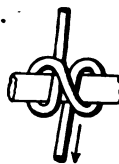
Bowline



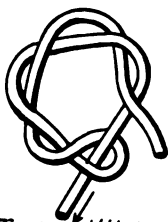
Bowline on a bight



Clove Hitch



Half Hitch



Timber Hitch



2 Half Hitches



Round turn & 2 half hitches

USEFUL KNOTS

677.7



Lever Hitch



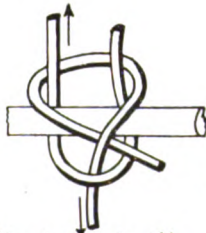
Catspaw



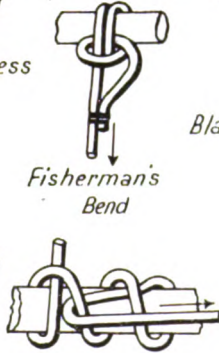
Man's Harness Hitch



Blackwall Hitch



Sheet Bend with Toggle



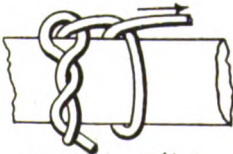
Fisherman's Bend



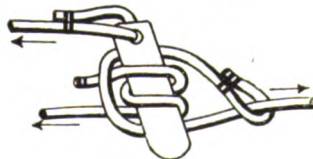
Rolling Hitch



Hangman's Knot



Timber Hitch Half Hitch



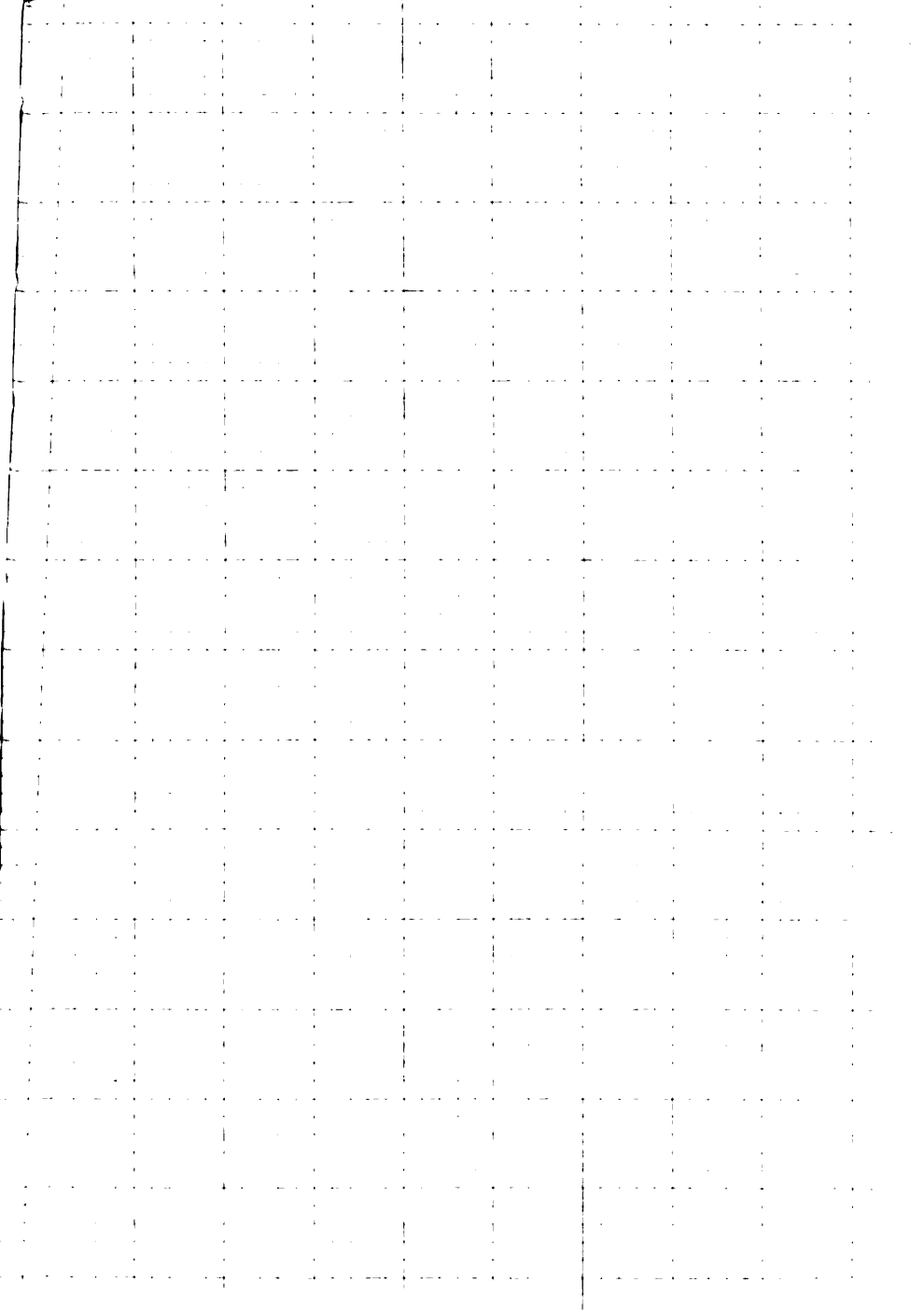
Slip Rope

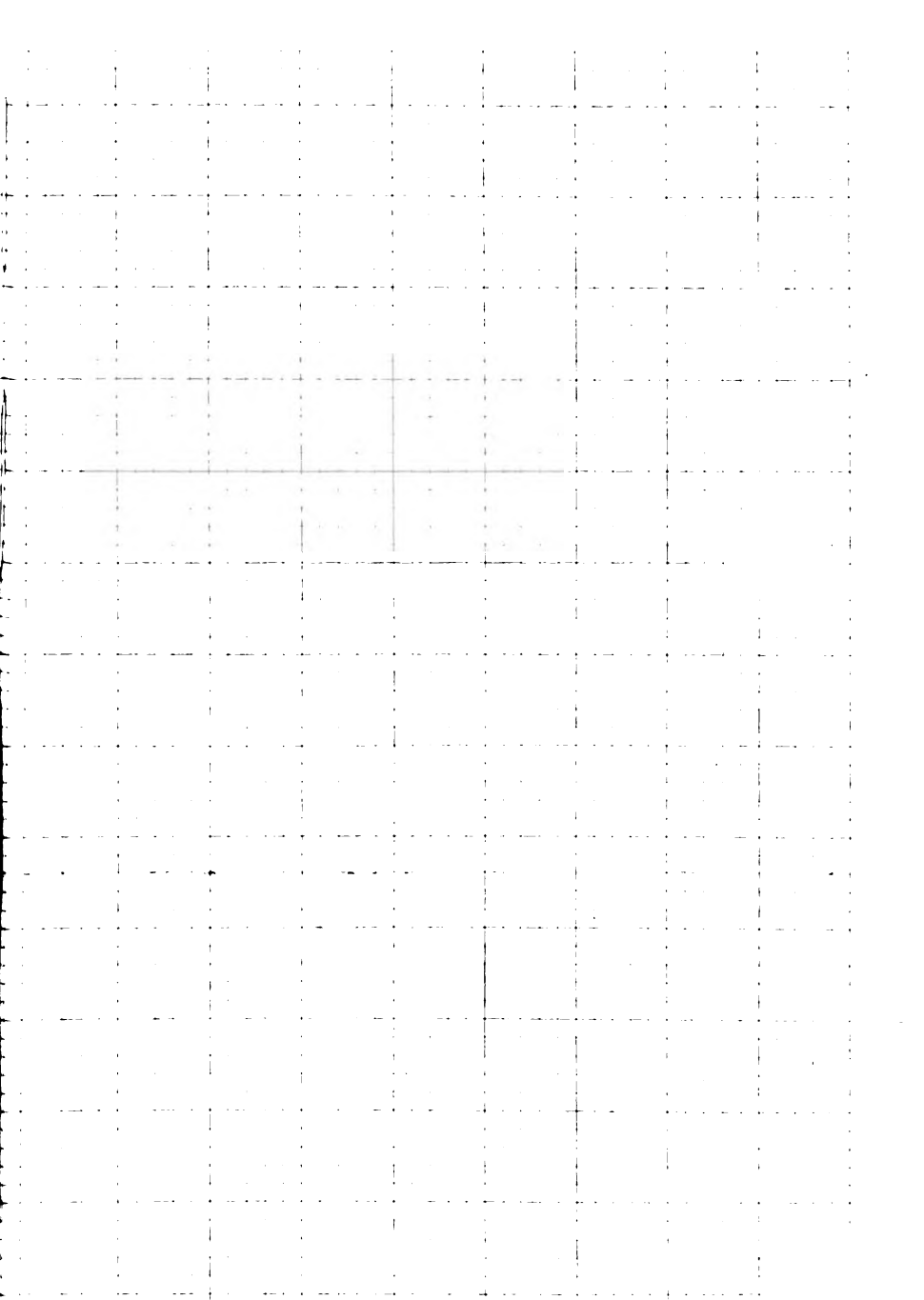


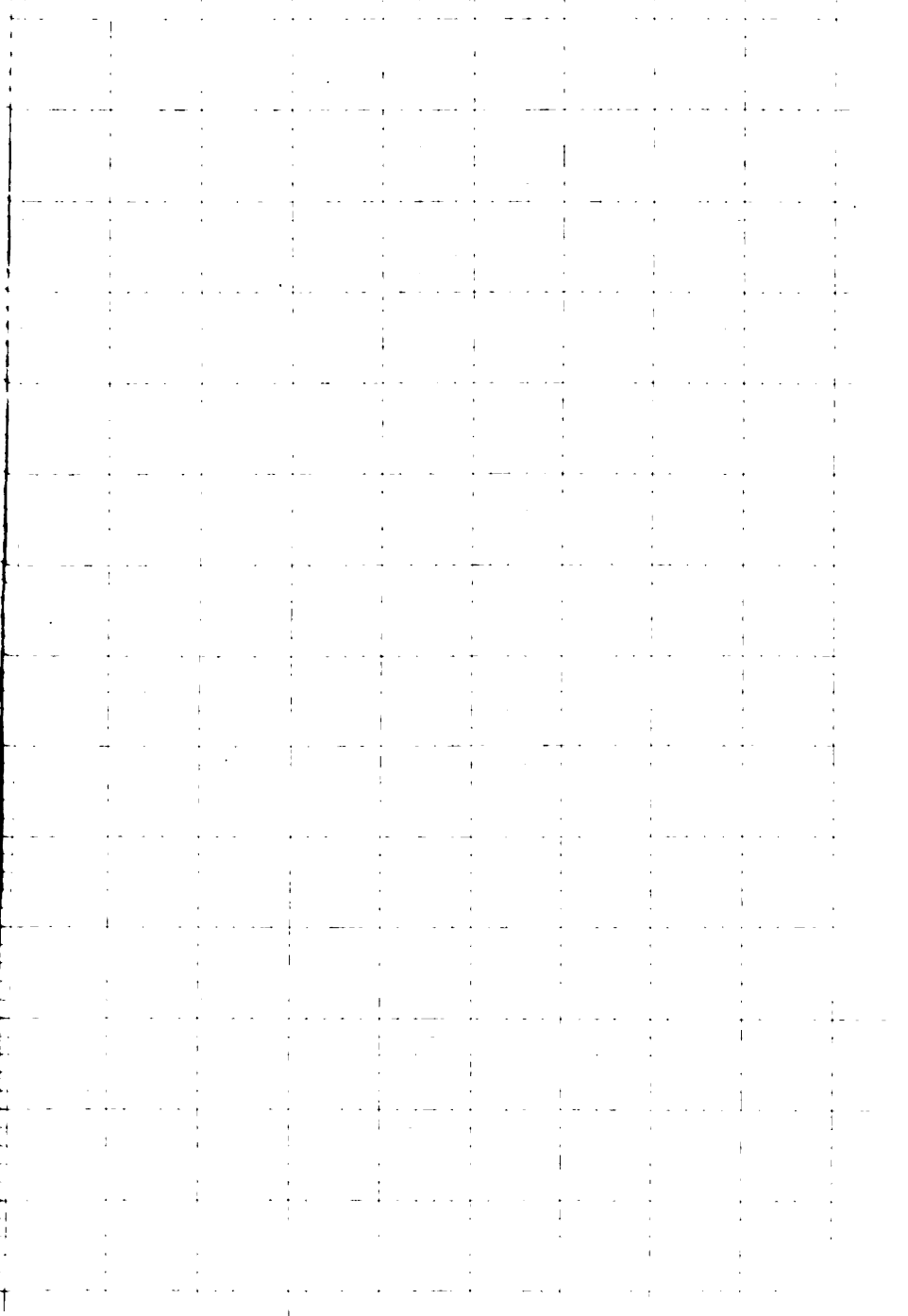
LIFTING SURFACE IN SQ:FEET.

In connection with this diagram refer to pp. 78-85.

U.E.D.A. (Detachable Data) System
Borlase Mathematics Patents (provisionally protected). U.S. Patents applied for.







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1919-20

A DIRECTORY OF MANUFACTURERS

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THE following directory comprises concerns that specialise in the various branches of the aviation industry in Great Britain, and as it is the most complete, compact, and up-to-date list that has yet been published, it will doubtless be found very useful for daily reference. It does not pretend to include the names of all who are accustomed to making aeroplane parts, for many firms were doing so for the period of the war only—in fact there is hardly a motor car or motor car accessory or wood-working firm that was not fully occupied with aviation work at the time of the Armistice. Many will certainly continue to devote attention to this branch now peace is declared, as the aviation industry will in future be established on a stable basis that did not exist before the war. There are, of course, many manufacturers who have suitable machinery for making aeroplane parts, but as they do not specialise in this work, their names have been omitted. Possibly, however, some names are not included that ought to be, since it is not an easy task, when compiling a directory of this nature, to ensure its being absolutely complete. Should any names have been overlooked, therefore, the author would be glad to have his attention drawn to the same, so that their insertion may be made in next year's "Aviation Pocket-Book."

According to the American journal, *Flying*, dated June 1917, "there are 958 firms in England engaged on the manufacture of aeroplanes. 301 of these are direct contractors, and 657 are sub-contractors."

ACCUMULATORS—Pritchett & Gould and Electrical Power Storage Co. Ltd., 50 Grosvenor Gardens, Victoria, London, S.W. 1. "Storage, Sowest, London". [Victoria 3181]

ACETYLENE—See Welding.

ADDING MACHINES—Burroughs' Adding Machine Ltd., 76 Cannon St., E.C. 4. [City 7497]

AEROPLANE MANUFACTURERS—(* Indicates a propeller branch.)

Adam Grimaldi & Co., Albert Embankment, S.E. 11	.	.	.	.	[Hop 5552]
Aircraft Construction Co., Beckton Road, E. 16.	.	.	.	.	[East 1300]
Aircraft Manufacturing Co. Ltd., Hendon	.	.	.	.	[Victoria 3688, Kingsbury 22]
Alliance Aircraft Co. Ltd., 45 Castle St. East, W. 1	.	.	.	.	[Museum 5000]
Alford and Alder, 53 Newington Butts	.	.	.	.	[Central 12936]

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AEROPLANE MANUFACTURERS (*continued*)—

Angus, Sir Wm. Sanderson & Co., St Thomas Street, Newcastle-on-Tyne	
[Newcastle Central 3706, Carlisle 238, Penrith	71
Armstrong, Sir W., Whitworth & Co. Ltd. , Newcastle-on-Tyne [Vict. 4010, Gosforth	500
Arrol Johnston & Co.	[Dumfries 281
*Austin Motor Co. Ltd. , Northfield Works, Birmingham	[Kings Norton 230
*Barker & Co. Ltd. , 66-68 South Audley Street, W.	[Mayfair 7110-7114, Park 4901-5
Beardmore Aero Engineering Co. Ltd., 112 Great Portland Street, W.	[Gerrard 238
*Beardmore, Wm., & Co. Ltd. , Dalmuir	[Victoria 4678, Clydebank 240
Berwick, F. W., & Co. Ltd., 18 Berkeley Street, W.	[Gerrard 3259, Willesden 2490
*Blackburn Aeroplane & Motor Co. Ltd. , Olympia, Leeds (& Hull)	[Roundhay, 345
Blake, J., & Co., 22 Rodney Street, Liverpool	[Royal 4085, 4088
Bleriot Aeronautics, Brooklands, Byfleet, Addlestone, Surrey [Byfleet 190, Weybridge	353
*Boulton & Paul Ltd. , Rose Lane, Norwich	[Central 4642, Norwich 851
Brighton Motor Coach Works, Brighton	[Kemp Town 6992
*Brinsmead, John, & Sons Ltd. , 18-22 Wigmore St., W. [Mayfair 1243 & 3524, Hampstead 6005	
British Aircraft Manufacturing Co., Belfast Road, Stamford Hill, London [Dalston 3206	
*British & Colonial Aeroplane Co. Ltd. , Filton, Bristol. "Aviation, Bristol" [Bristol 3906	
British Caudron Co. Ltd., Broadway, Cricklewood, N.W. 2 [Alloa 52, Hampstead 4647	
British Wright Co. Ltd., 33 Chancery Lane, London, W.C.	
*Brush Electrical Engineering Co. Ltd. , Loughborough [Holborn 2682, Loughborough 624	
Burton Aircraft and Manufacturing Co., Burton-on-Trent	
Caffyns Garrages Ltd., Meads Road, Eastbourne	[Eastbourne 861
Camper & Nicholson, Gosport, Hants	[Gosport 4
Central Aircraft Co. , 179 High Road, Kilburn, N.W. 6	[Hampstead 4403-9
Chelsea Aviation Co. Ltd., 30 Whiteheads Grove, Chelsea, S.W. 3	[Kensington 1360
Clayton & Shuttleworth, Lincoln	[Lincoln 43
Cleaver, H. C., Ltd., 35 Berner Street, W.	[Museum 2693, Wembley 41
Clyde Shipbuilding and Engineering Co., Glasgow	[Port Glasgow 98
*Cohen, B., & Sons Ltd. , 1-19 Curtain Road, E.C.	[London Wall 3729
Cole, Wm., & Sons Ltd. , 235 Hammersmith Road, London, W.	[Hammersmith 1413
Courtney Pope & Co. Ltd. , 6-9 Alpha Place, Caledonian Road, N.	[Central 8654
Coventry Ordnance Works Ltd., Coventry	[Victoria, 5550, Coventry 1201
Cowper-Coles Aircraft Co., Sunbury-on-Thames	[Sunbury 37
*Cravens Ltd. , 68 Victoria Street, S.W.	[Victoria 4611, Sheffield 4589
Curtiss Aero Motor Corporation, 17 Surrey Street, Strand, W.C.	[City 7724
*Curtiss, J., & Son, Oxford Row, Leeds	[Leeds 453
Daimler Ltd., Coventry	[Regent 930, Coventry 505
*Darracq Ltd. , Townmead Road, Fulham	[Mayfair 5607, Putney 2560
*Davidson Aviation Co. Ltd. , Hammersmith, W. 6	[Hammersmith 1992
Dawson, John, & Co. (Newcastle) Ltd. , Newcastle, and 20 Victoria St., S.W. 1 [Victoria 6062	
Denny, Wm., & Bros., Dumbarton	
*Dove Bros. Ltd. , Cloudesley Place, Islington, N.	[North 1894
Dutton Aircrafts, 52 Bridge Street, Chester	
Eastbourne Aviation Co. Ltd., Eastbourne. "Aircraft, Eastbourne"	[Eastbourne 1176
English Electric Co. Ltd., Thornbury Works, Bradford	[Bradford 3700
Estler Bros., S. Molton Road, Victoria Docks	[East 1870
Evans, Joseph, & Sons, P., Wolverhampton	[Cent. 706, Wolverhampton 39
Fairey Aviation Co., Hayes, Middlesex	[Hayes 19
*Farrington Engineering Co. Ltd. , 399 Victoria Street, S.W.	[Victoria 1338
*General Aeronautical Co. Ltd. , 30 Regent Street, W.	[Gerrard 280

DIRECTORY OF MANUFACTURERS

AEROPLANE MANUFACTURERS (*continued*)—

Gilbert, W. Villa, & Co., 7 Princes Street, Westminster, S.W.	[Victoria 7089]
Glendower Aircraft Co. Ltd., Sussex Place, South Kensington, S.W. 7	[Kensington 7006]
Gosport Aircraft Co., Gosport and Southampton	[Gosport 217, Southampton 1861]
*Grahame-White Aviation Co. Ltd., London Aerodrome, Hendon, N.W. 9	[Kingsbury 120]
Handley Page Ltd., 110 Cricklewood Lane, N.W. 2	[Hampstead 7500]
Hardingham Bros., Church Road, Battersea	..
Harris & Sheldon, 70 Wood Street, E.C.	[City 766, Birmingham Central 6547]
Heaton, Aldam & Co., 156 New Bond Street, W.	[Regent 2064]
*Herman & Phillips, Acton Street, Kingsland Road, N.E.	[Dalston 530 and 1007]
Hewlett & Blondeau Ltd., Oak Road, Leagrave, Luton	[Leagrave 13]
Hewlett & Blondeau Ltd., 55 St James's Street, S.W., 77 King's Road, S.W.	[Regent 912, Kensington 4762]
Highbury Aircraft Co., 1A and 45 Rosebery Avenue, E.C. 1	[Holborn 922]
Highgate Aircraft Factory, Highgate	[Hornsey 2280]
Hoods & Bodies Ltd., Northampton Grove, Canonbury	[Dalston 3037]
Hooper & Co., 54 St James's Street, S.W.	[Regent 912, Kensington 4762]
*Horsman, Thos., 10-12 Mark Lane, Leeds	[Leeds 900]
Jouques Aviation Works, Willesden, London, N.W.	..
*Kearley, C. F., Ltd., 4 Gt. Marlborough St. W. [City 8742, Gerrard 4412, Hammersmith	467]
Kingsbury Aviation Co.	[Kingsbury 170]
Lock, W. & T., Bristol Road, Bath	[Western 14]
London Aircraft Co. Ltd., 5 Urswick Road, Lower Clapton, E. 9	[Dalston 25]
Lord, W. Turner, & Co., 20 Mount Street, W. 1	[Gerrard 5273, North 2454]
Mann, Egerton & Co., 379-381 Euston Road, N., and Norwich	[Museum 70, Norwich 482]
*Maple & Co., 149 Tottenham Court Road, W.	[Museum 7000]
*Marsh, Jones & Cribb Ltd., Leeds	[Mayfair 4410, Leeds 594]
Marston, Ltd., Paul Street, Wolverhampton	..
Martinsyde Ltd., Brooklands, Byfleet, Surrey	[Woking 321, Byfleet 171]
May, Harden & May Ltd., Kingston Bridge Boathouse, Hampton Wick	[Kingston 12]
*Messenger & Co. Ltd., 122 Victoria Street, S.W.	[Victoria 1209]
Morgan & Co. Ltd., 10 Old Bond Street, W.	[Mayfair 1188]
*Morris & Co., 79 Lots Road, S.W. 10	[Kensington 6310]
Motor Macs. Ltd., Bournemouth	..
Napier, D., & Sons Ltd., Acton, London, W.	[Chiswick 1220]
Napier & Miller, Shipbuilding Yard, Old Kirkpatrick	..
National Aircraft Manufacturing Co. Ltd., 15 Drummond Cres., N.W. 1	[London Wall 6725]
Navarro Aviation Co., Burton-on-Trent	..
Nestler, F. C., Ltd., Greycoat Street, Westminster	[Victoria 4122, North 190]
Nieuport & General Aircraft Co. Ltd., Langton Rd., Cricklewood, N.W. 2	[Wilkesden 2455]
Norman Thompson Flight Co., Ltd., Middleton, Bognor	[Bognor 48, London Gerrard 7385]
North British & Loco Co. Ltd., Springburn, Glasgow	..
Oakley Ltd., 28 Duke Street, Piccadilly	[Gerrard 2242]
*Ogilvie & Co., Mildmay Avenue, Newington Green Road, N.	[Dalston 1388]
*Parnall & Sons, Mivart Street, Bristol	..
Patey & Co. Ltd., 45 Horseferry Road, S.W. 1	[Victoria 2511]
Petters Ltd., Yeovil	[Yeovil 129]
P. D. V. Aircraft Spares, Princes Street, Richmond. "Aeros, Richmond"	[Richmond 1681]
Poole Aviation Co., 24 West Quay Road, Poole, Dorset	[Poole 54]
Portass & Son, Broadfield Road, Sheffield. "Portal, Sheffield"	..
*Protholme Aerodrome Ltd., St John's Street, Huntingdon	[Huntingdon 26]

THE AVIATION POCKET-BOOK

AEROPLANE MANUFACTURERS (*continued*)—

- *Prestige & Co. Ltd., Cambridge Wharf, Grosvenor Road, S.W. (Victoria 6030 and 1812)
- Ransome, Simms & Jeffries Ltd., Ipswich (Central 10817, Ipswich 12)
- Regent Carriage Co. Ltd.**, New King's Road, Fulham, S.W. 0 (Putney 2240)
- Robey & Co.**, Lincoln (Lincoln 2 and 3)
- ***Roe, A. V., & Co. Ltd.**, Newton Heath, Manchester, and 106 Piccadilly, W. 1
(Gerrard 3186, Manchester City 8530-31)
- Rudge Whitworth Ltd., Coventry (Coventry 1104)
- Ruffy-Baumann Aeroplanes, London Aviation Ground, Acton
- *Ruston Proctor Ltd., 46 Queen Victoria Street, Lincoln (City 5148, Lincoln 58L)
- *Sage, Fredk., & Co., 58-62 Gray's Inn Road (Holborn 2664)
- Saunders, S. E., Ltd., East Cowes, Isle of Wight (Cowes 103)
- Savages Ltd., King's Lynn, Norfolk (Victoria 7026)
- *Shapland & Petter, 62 Oxford Street, W. (Museum 1434, Barnstaple 9)
- Sheffield Simplex Motor Works Ltd., Sheffield
- *Short Bros., 29-30 Charing Cross, and Rochester (Regent 378, Eastchurch 9)
- Siddeley Deasy Motor Car Co. Ltd., Parkside, Coventry (Regent 6440, Coventry 954)
- Sopwith Aviation Co. Ltd.**, Kingston-on-Thames (Kingston 1988)
- Standard Aircraft Manufacturing Co. Ltd.**, Effingham House, Arundel Street,
Strand, W.C. 2; 28 Bow Common Lane, E. 3 (City 89, East 3832)
- Standard Motor Co., Coventry (Coventry 530)
- Stanley Aviation Co.**, Chatham Place, Morning Lane, Hackney, N.E. (City 347)
- Sturtevant Engineering Co. Ltd.**, 147 Queen Victoria Street, E.C. (Central 7121)
- Sunbeam Motor Co., Wolverhampton (Museum 124, Wolverhampton 985)
- Supermarine Aviation Works Ltd., Woolston, Southampton (Woolston 37)
- *Tamworth, Hindley & Co., 26 Buckingham Gate, S.W. (Victoria 5745)
- Tarrant, W., Byfleet (Byfleet 1, Gerrard 8362)
- Thames Aviation Works Ltd.** (Burtons Ltd.), 141 Curtain Road, E.C. 2 (London Wall 9766)
- The Croydon Aviation and Engineering Co. Ltd., Effingham House, Arundel Street,
Strand, W.C. 2; 35 Queen's Res., High Wycombe, and 57A Southend, Croydon
- *Tibbenham's Aviation Co., Portland Road, Ipswich (Ipswich 505)
- *Trevor, Page & Co., Exchange Street, Norwich (National 238, Norwich 238)
- *Trollope, Son & Colls, 77 Grosvenor Road, S.W. (Victoria 1971)
- United Aircraft Co. Ltd., 4 Gt. Marlborough Street, W. 1 (Gerrard 8169)
- Vickers Ltd. (Aviation Dept.)**, Imperial Court, Knightsbridge, S.W. 3
(Kensington 6810, Dartford 180, Ipswich 844)
- Vulcan Motor Co. Ltd., Crossens, Southport, Lancs. (Southport 1348)
- Wakefield, C. C., & Co. Ltd.**, Wakefield House, Cheapside, E.C. 2
- Waring & Gillow, 164-180 Oxford Street (Museum 5000, Hammersmith 1980)
- *Watling, R. S., & Sons, The Maltings, Great Yarmouth (Great Yarmouth 130)
- Watney, Gordon & Co., Weybridge (Weybridge 550)
- *Westland Aircraft Co., Yeovil (Yeovil 129)
- White, Allom & Co. Ltd., 15 George Street, Hanover Square (Gerrard 5716)
- *White, J. Samuel, & Co. Ltd., East Cowes, Isle of Wight (Victoria 4507, Cowes 3)
- Whitehead Aircraft Co.**, Richmond, Surrey; Lily Road, Fulham
(Richmond 1865-1867, Western 1603)
- *Wolseley Motors, Alderley Park, Birmingham (Victoria 6220, Central 4561)
- *Wm. Willett, Sloan Square, S.W. 1 (Kensington 4660)
- Wright & Sons Ltd., Quorn Hills, near Loughborough (Loughborough 659)
- Wycombe Aircraft Constructors Ltd., 57 Lond. Rd., H. Wycombe, Bucks (H. Wycombe 84)
- Wylie & Lochhead, 45 Buchanan St., Glasgow (Central Glasgow 5730 and 6890)

DIRECTORY OF MANUFACTURERS

AIRSHIPS—

Airships Ltd., High Street, Merton, and 47 Victoria Street, S.W. 1	[Wimbledon 1314]
Armstrong, Sir W., Whitworth & Co.	[Victoria 4010]
Short, Bros., Rochester, Eastchurch, and Whitehall House, S.W.	[Regent 378]
Spencer & Sons, C. G., 50A Highbury Grove, N. 5.	"Aeronaut, London" [Dalston 1892]
Wortman, B., & Son, Waterloo Street, Hammersmith	[Hammersmith 908]

AVIATION ACCESSORIES—Also refer to Metal Parts and Fittings.

A. Beebee, General Aviation Contractors Ltd., Wednesbury	..
Accles & Pollock Ltd., Oldbury, Birmingham	[Oldbury 111]
Aero Mechanical Co. Ltd., 66 Rochester Row	[Victoria 7570]
A.G.S. Manufacturing Co. Ltd., 4 and 5 Norfolk Street, Strand, W.C. 2	[Central 1446]
Allens & Simmonds Ltd., Reading, Berks	..
Barimar Ltd., 10 Poland Street, Oxford Street, London, W.	[Gerrard 8178]
Bayliss, Jones & Bayliss Ltd., Wolverhampton, and 139-141 Cannon Street, E.C. 4	[Bank 889, and Central 8524]
Benton & Stone, Birmingham	..
Blackburn Aeroplane & Motor Co. Ltd., Olympia, Leeds	[Roundhay 345]
Bowden Brake Co. Ltd., Tyseley, Birmingham	..
Rowden Wire Ltd., Victoria Road, Willesden Junction, N.W. 10	[Wilkesden 2400]
British Chuck & Piston Ring Co. Ltd., Holbrook Lane, Coventry	[Coventry 723]
Brown Bros. Ltd., Great Eastern Street, London, E.C. 1	[London Wall 6300]
Cashmore Brothers (Metric Bolts and Nuts), Hildreth St., Balham, S.W. 12	[Battersea 415]
Central Aircraft Co., Palmerston Works, High Road, Kilburn, N.W. 6	[Hampstead 4403]
C. G. Spencer & Sons Ltd., 56A Highbury Grove, London, N. 5	[Dalston 1893]
Dermatine Co. Ltd., 93 and 95 Neate Street, S.E.	[Hop 31]
Dover Ltd., 35 Hatton Garden, E.C. 1	[Holborn 268]
Evans, Joseph, & Co. Ltd., Liverpool Street, Birmingham	[Central 733]
Fredk. Mountford Ltd., Lifford, Birmingham	..
Gabriel & Co., 4 and 5 A. B. Row, Birmingham.	"Gabriel" [Central 1223]
Goldsmiths & Silversmiths Co. Ltd., 112 Regent Street, W.	..
Haywards Ltd., Union Street, Borough, S.E. 1	[Hop 3642]
Jacobs, W. A. & R. J., Ltd., 94 Leonard Street, E.C. 1	[Central 6938]
MacLennan, J., & Co., 30 Newgate Street, E.C. 1, and at Glasgow (Tapes, Webs, Cords, and Threads)	[City 3115]
Mann, Egerton & Co. Ltd., Norwich	..
Menday Motor Components Co. Ltd., Gatten Rd., Tooting, London, S.W. [Battersea 1917]	
Morris, Russell & Co. Ltd., 75 Curtain Road, E.C. 2	[London Wall 5143]
Moss, W., 52 High Street, W.C. 2	[Gerrard 6731]
National Aircraft Manufacturing Co., 15 Hackney Road, London, N.E. [London Wall 6725]	
P. D. V. Aircraft Spares, Syon Chambers, 16A Kew Rd., Richmond, Surrey [Richmond 1681]	
Rivers Engineering Co. Ltd., 27 Lots Road, Chelsea, S.W. 10	[Kensington 8116]
Rotax Motor Accessories, 43 Gt. Eastern St., E.C. 1, and Willesden Junction, N.W.	[London Wall 2361, and Willesden 2430]
Rubery, Owen & Co., Darlaston, South Staffs.	..
The Aero Mechanical Co. Ltd., 60-66 Rochester Row, S.W. 1	[Victoria 7570]
The Aircraft Construction Co., Beckton Road, E. 16	[East 1300]
The Aircraft Supplies Co. Ltd., 125 Long Acre, W.C. 2	[Gerrard 276]
The General Aeronautical Co. Ltd., 30 Regent Street, London, W.	[Gerrard 280]
The Osborne Aircraft Co. Ltd., Whin Hill, Greenock, Scotland	[Greenock 618]
T. W. K. Clarke & Co. Ltd., High Street, Hampton Wick	[Kingston 969]

THE AVIATION POCKET-BOOK

AVIATION ACCESSORIES (*continued*)—

Whitehead Aircraft Co. Ltd. , Townshend Road, Richmond, Surrey	[Richmond 1865]
Whiteman & Moss Ltd. , 35 Long Acre, W.C. 2	[Gerrard 6824]
Whitfield Aviation Ltd. , 10 Dane Street, W.C.	[Holborn 409]
Wooler Engineering Co. Ltd. , Willesden Junction, London, N.W.	[Willesden 117]

AIRCRAFT RIGGING—See Wires.

AIR-SCREWS—See Propellers.

ALLOYS—See Metals.

ALUMINIUM—Castings.

Blackwell, G. G., Sons & Co. Ltd. , The Albany, Liverpool	[Blackwell, Liverpool, Central 952]
Vowles Brothers , Hull End Foundry, West Bromwich	[West Bromwich 3002]
William Mills Ltd. (Castings), Grove Street, Birmingham	..

ANTI-FRICTION METALS—See Metals.

ASBESTOS—

Bell's United Asbestos Co. Ltd. , Southwark Street, London, S.E.	[Hop 4040]
Cape Asbestos Co. Ltd. , 23 King Street, Cheapside, London, E.C.	[City 598]
The Aerolite Piston Co. Ltd. , Hanover Court Garage, Hanover St., London, W.	[Gerrard 7905]

AVIATION GARMENTS—See Clothing.

BALL BEARINGS—

Garrard, C. R., Ltd. , 45 Endell Street, W.C. 2	[Regent 2388]
Hoffmann Manufacturing Co. Ltd. , Chelmsford	..
Norris, Laurence & Co. , Imperial Buildings, Kingsway, London, W.C.	[Holborn 5743]
The Skefko Ball Bearing Co. Ltd. , Luton	..

BEARING METALS—See Metals.

BELTING—**Dermatine Co. Ltd.**, Neate Street, London, S.E. [Hop 31]

BENT TIMBER PARTS—See Timber.

BOLTS, NUTS, SCREWS, STUDS, ETC.—See Aviation Accessories.

BRAKE AND CLUTCH LININGS—**Herbert Frood & Co. Ltd.**, Chapel-en-le-Frith

BUILDING, CONCRETE MIXERS—**Ransome-Yermehr Machinery Co. Ltd.**, Brunswick House, 2 Central Buildings, S.W. 1. "Vermehrco, London" [Victoria 2188]

BUILDINGS, HANGARS, ETC.—

Archibald D. Dawney & Sons Ltd. , Battersea, London, S.W.	[Battersea 1094]
Aston Construction Co. Ltd. , Eagle Wharf Road, London, W.	[North 1808]
Boulton & Paul Ltd. , Rose Lane, Norwich. "Aviation Norwich"	[Norwich 851]
Building Construction Co. Ltd. , 50 Osnaburgh Street, N.W. 1	[Museum 1489]
Croggon & Co. Ltd. , 16 and 230 Upper Thames Street, E.C. 4	[City 3067]
D. Anderson & Son Ltd. (Roofing), Belfast, and Roach Road, Old Ford, E.C.	[East 3214]
Dawney, A., & Son , Steelworks Road, Battersea, S.W. 1	[Battersea 1094, 1095]
F. C. Nestler Ltd. , Greycoat Street, Westminster, London, S.W.	[Victoria 4122]
Haywards Ltd. (Supplies), Union St., S.E. 1. "Hayward Brothers, London"	[Hop 3642]

DIRECTORY OF MANUFACTURERS

BUILDINGS, HANGARS, Etc. (*continued*)—

J. Putman, Southern Works, Aylesbury. "Putman"	[Aylesbury 57
Kenyon Iron Works Co. Ltd., 231-2 Strand, London, W.C.	[Central 5315
Maréchal & Hervieu, 166 Piccadilly, W.	[Regent 3031
Messenger Brothers Ltd., Hounslow. "Messenger, Hounslow"	[Hounslow 6
Palmer, T. W., & Co., Church Road, Mertoun Abbey, Surrey	[Wimbledon 1313
Ruberoid Co. Ltd. (Roofing), 31-3 Knightrider Street, London, E.C.	[City 9880
Rubery Owen & Co., Darlaston, South Staffs	..
Spiers Ltd., 13 Blythswood Square, Glasgow	..
The Fairby Construction Co. Ltd., 317 High Holborn, W.C.	[Holborn 1875
The Trussed Concrete Steel Co. Ltd., 116 Caxton House, W'minster, London, S.W. [Vic. 1296	
The Witley Co. Ltd., Salisbury House, London Wall, E.C. 2.	[City 2681-2
Williams & Williams Ltd., Chester. "Reliance, Chester"	[Chester 765
Wire Wove Roofing Co., 100 Queen Victoria Street, London, E.C.	[Central 4574

CAST-IRON MOTOR CYLINDERS—William Mills Ltd. (Castings), Grove Street, Birmingham

CARBURETTORS—

H. M. Hobson Ltd., 29 Vauxhall Bridge Road, London, S.W. 1	[Victoria 4670
The Zenith Carburettor Co. Ltd., 40-42 Newman Street, London, W. 1	[Regent 4812
White & Poppe Ltd., Coventry	..

CASTINGS—See Metals.

CELLULOID—

Greenhill & Sons, 8 Water Lane, E.C. 4. "Greenberg, London"	[Central 1306-7
London Label Co., Beckett Road, E. 16. "Lonlabel, Canning, London"	[East 1300
The Hughes Label Co. Ltd., Enfield	[Enfield 543

CHAIN DRIVES—

Hans Reynolds Ltd., Didsbury, Manchester	..
The Coventry Chain Co. Ltd., Coventry	..
Westinghouse Brake Co. Ltd. (Morse), 82 York Rd., King's Cross, London, N. [North 2416	

CLOTHING—

A. W. Gamage Ltd., Holborn, London, E.C.	[Holborn 2700
Brown Bros. Ltd., Great Eastern Street, London, E.C.	[London Wall 6300
Burberry's, Haymarket, London, S.W. 1. "Burberry, Charles, London" [Regent 2165-6-7	
C. H. Holmes & Son (Safety Belts), Albert Street, Manchester	..
Dunhills Ltd., 2 Conduit St., London, W.1, 359 Euston Rd., N.W. 1 [Gerrard 3850, North 3405	
Flights Ltd., 4 New Burlington Street, W.	[Regent 2346
Gamage Ltd., Holborn, E.C. 1	[Holborn 2700
Gieves Ltd., 65 South Molton Street, W. 1	[Mayfair 6504
Glen & Powell Ltd., 18A London Street, E.C.	[Central 13170
Harrods Ltd., London, S.W.	[Western 1
Hazel & Co., 4 Princes Street, Hanover Square.	[Mayfair 4071-2
Hobson & Sons (London) Ltd., 27 Maiden Lane, Strand, W.C.	[Gerrard 3459
Junior Army & Navy Stores Ltd., 15 Regent Street, W.	[Gerrard 4370
Morris Angel & Sons Ltd., 117 Shaftesbury Avenue, W.	..
Robinson & Cleaver Ltd., Regent Street, London, W. 1	[Gerrard 1070
Ross Bros. & Co. Ltd., 20-21 King St., Covent Garden, London, W.C.	..
Swan & Edgar Ltd., Waterloo House, Piccadilly, W.	..

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COMMERCIAL MOTORS—See Motor Vehicles.

COMPONENT PARTS—See Aviation Accessories.

COPPER AND BRASS RODS, SHEETS, TUBES, ETC.—See Metals.

CORDS—See Fabrics, Cords, and Yarns.

CORDS AND THREADS—MacLennan, J., & Co., 30 Newgate Street, E.C. 1; and at Glasgow. (Kite, Binding, and Sewing Cords.) [City 311]

DERMATINE—Dermatine Co. Ltd., 93 and 95 Neate Street, S.E. [Hop 31]

DIE CASTINGS—See Metals.

DOPES—See Varnishes.

DRYING KILNS—See Timbers.

DUST COLLECTING AND REFUSE REMOVAL—Sturtevant Engineering Co. Ltd., 147 Queen Victoria Street, E.C. [Central 7121]

ELECTRICAL ACCESSORIES—

Edison-Swan Electric Co. Ltd., 123-125 Queen Victoria Street, Enfield [Enfield 520]
 E. Kalker & Co., Coventry. "Kalker, Coventry" [Coventry 24x]
 Johnson & Phillips Ltd., Charlton, London, S.E. 7 [Central 178 and 2207, Greenwich 400]
 Mann, Egerton & Co. Ltd., 177 Cleveland Street, London, W. 1 [Museum 70]
 Premier Electric Heaters Ltd., 258, 259 and 260 Bradford St., Birmingham [Midland 981]

ELECTRO-GALVANISERS—Deptford Steel & Iron Works Ltd., Old Pye Street, Westminster [Victoria 4607-8]

ELECTRIC PLANT—Johnson & Phillips Ltd., Charlton, S.E. [Greenwich 400]

ELECTRIC CABLES—Johnson & Phillips Ltd., Charlton, S.E. [Greenwich 400]
 Kalker, E., & Co., Coventry. "Kalker, Coventry" [Coventry 24x]

ELECTRIC TELEPHONES (for Aeroplanes)—

Alfred Graham & Co., St Andrew's Works, Crofton Park, London, S.E. [Sydenham 952]
 Mears Earphone Co. (London) Ltd., 193 Regent Street, London, W. [Regent 5755]

ENGINES AND PARTS—

A.B.C. Motors Ltd., Walton-on-Thames
 Aircraft Supplies Co. Ltd., "Ascol House," 125 Long Acre, W.C. 2 [Gerrard 276]
 Allen, W. H., Son & Co. Ltd., Bedford [Bedford No. 1]
 Arrol-Johnston Ltd., Dumfries. "Mocar, Dumfries" [Dumfries 231, 252]
 Austin Motor Co. (1914) Ltd., Northfield, Birmingham [King's Norton 230]
 Beardmore Aero Engineering Ltd., 112 Great Portland Street, W. 1 [Gerrard 238]
 Beverley Engineering Works, Barnes [Putney 478]
 Blackburn Aero and Motor Co. Ltd., Olympia, Leeds
 British Anzani Engineering Co. Ltd., 31-33 Scrubbs Lane, Willesden Junction, N.W. 10 [Willesden 2214, Gerrard 280]
 Cosmos Engineering Co. Ltd., 16 Pall Mall, S.W. [Regent 1476]
 Crossley Motors Ltd., Manchester [City 4611, Motors, Garton]
 Curtiss Aeroplane & Motor Co., Clun House, Surrey Street, W.C. 2 [City 7724]

DIRECTORY OF MANUFACTURERS

ENGINES AND PARTS (*continued*)—

Daimler Co. Ltd., Coventry and London.	[Regent 930
Darracq Motor Engineering Co. Ltd., Townmead Road, Fulham, London, S.W.	[Putney 2560 and 1892, Mayfair 5007
Dermatine Co. Ltd., 93 and 95 Neate Street, E.C.	[Hop 31
Dudbridge Iron Works Ltd. (Salmson), Stroud (Glos.) & 87 Vict. St., London, S.W. 1	[Vict. 7026
Evans, Joseph, & Co. Ltd., Liverpool Street, Birmingham	[Central 733
Gnome & Le Rhone Engine Co. Ltd., 47 Vict. St., S.W. (P. Hooker Ltd.)	[Walthamstow 811
Gordon Watney & Co. Ltd., Weybridge. "Mercédès, Weybridge"	[Weybridge 550
Green Engine Co. Ltd., Twickenham	[Richmond 1293
Gwynnes Ltd., Hammersmith, W.	[Hammersmith 1910
Napier, D., & Son Ltd., 14 New Burlington St., London, W., and at Acton, W.	
"Nitrifier, London"	[Chiswick 1220, Gerrard 8926
Omnium Central, 29 Red Lion Square, W.C. 1	
Robertson, J. H., & Co., 1 Albemarle Street, London, W. 1	[Regent 3096
Rolls-Royce Ltd., 14 and 15 Conduit St., W. 1. "Rollhead, London"	[Gerrard 1654-5-6
Selsdon Aero & Engineering Co. Ltd., 1 Albemarle Street, Piccadilly, W. 1	[Regent 1181
Siddeley-Deasy Motor Car Co. Ltd., Coventry	[Coventry 954
Standard Motor Co. Ltd., Cash's Lane, Coventry	[Coventry 530
Sturtevant Engineering Co. Ltd., 147 Queen Victoria Street, London, E.C.	[Central 7121
Sunbeam Motor Car Co. Ltd., Wolverhampton	[Wolverhampton 955
The Beatty School of Flying Ltd., The Broadway, Cricklewood, N.W. 2	[Hampstead 3000
Vickers Ltd., Basil Street, Knightsbridge, S.W. 3	[Kensington 6810
Vulcan Motor and Engineering Co. (1906) Ltd., Crossens, Southport	[Southport 1348
Walton Motors Ltd., Walton-on-Thames	
White & Poppe Ltd., Coventry	
Willans & Robinson Ltd., Rugby	[Rugby 112
Williams & Williams Ltd., Chester. "Reliance, Chester"	[Chester 765
Wolseley Motors Ltd., Adderley Park, Birmingham	[Central 4361

EYEBOLTS—See Aviation Accessories.

FABRICS, CORDS, AND YARNS—

Brown, Percy, & Co., 49 Newgate Street, E.C. 1. "Ominate, London"	[City 4659
Carr, J., & Sons Ltd., Chester Road, Manchester. "Car, Manchester"	[Central 1295
C. G. Spencer & Sons Ltd., 56A Highbury Grove, London, N.	[Dalston 1893
General Aeronautical Co. Ltd., 30 Regent Street, London, W.	[Gerrard 280
James North Hardy & Sons Ltd., 54 Portland Street, Manchester	[Central 6471
John MacLennan & Co. (Tapes, Webs, Cords), 30-31 Newgate Street, London, E.C., and 166 Ingram Street, Glasgow	[City 3115
Jones Bros. Ltd., 12 York Street, Manchester	
North British Rubber Co. Ltd., Edinburgh	
Stevenson & Sons Ltd., Dungannon, Co. Tyrone, Ireland	
William Heaton & Sons Ltd., Lostock Junction Mills, Bolton	
William Gschwind & Co., 211 Deansgate, Manchester	

FELTING AND ROOFING—See Buildings.

FLEXIBLE SHAFTS—

Herbert Terry & Sons Ltd., Redditch. "Springs, Redditch"	[Redditch 61
The Selsdon Aero & Engineering Co. Ltd., 1 Albemarle Street, Piccadilly, W. 1	
	[Regent 1181, Croydon 1761 and 883

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FLYING SCHOOLS—

Aeronautical Correspondence Schools, 13 Cedars Road, Chiswick	..
Beatty School of Flying Ltd., London Aerodrome, Hendon	[Kingsbury 138
Bournemouth Aviation Co. Ltd., Talbot Village, Bournemouth	.. [1160
British School of Aeronautical Engineering (Correspondence), 36 Maiden Lane, London, W.C., and 251 Oxford Road, Manchester	..
Eastbourne Aviation Co. Ltd., Eastbourne	..
Graham-White Aviation Co. Ltd. , London Aerodrome, Hendon, London, N.W.	[Kingsbury 120 and 121
Hall Aviation Co., London Aerodrome, Hendon	[Kingsbury 142
London and Provincial Aviation Co. Ltd., London Aerodrome, Hendon, London, N.W.	[Kingsbury 102
Midland School, Billesley Aerodrome, King's Heath, Birmingham	..
Northampton Polytechnic Institute (Lectures), 280 St John St., London, E.C. [Holborn 3072	
Northern Aircraft Co., Bowness-on-Windermere	..
Nottingham Flying & Correspondence Schools Ltd., 32 King Street	[Nottingham 5766
Ruffy-Baumann School, London Aviation Ground, Acton	[Chiswick 1219

GALVANISING—

Boulton & Paul Ltd., Rose Lane, Norwich. "Aviation Norwich"	[Norwich 851
Deptford Steel & Iron Works Ltd., Old Pye Street, Westminster	[Victoria 4607-8
Rustless Iron (Cowper Coles Process) Ltd., 1 French Street, Sunbury-on-Thames, Middlesex	[Sunbury 37

GLUES AND CEMENTS—

Adams & Co. Ltd., West Bromwich. "Reliance, West Bromwich"	[West Bromwich 264
B. Cannon & Co., Cannon Street House, E.C. 4	[City 1208
Central Chemicals Ltd., 283 West End Lane, London, N.W. 6	..
Col-Wa-Glue Ltd.	..
Fox Stockell Ltd.	..
Grove Chemical Co. Ltd. , Appleby Bridge, near Wigan	[Parbold 12
G. & J. Cox Ltd.	..
G. R. Lloyd Ltd.	..
Hobdell, Way & Co., 124-7 Minories, E.	..
Improved Liquid Glues Co. Ltd., Great Hermitage Street, E. 1 (Croid)	[Avenue 3178
Lactocol Manufacturing Co., Studley Road, Clapham, S.W. 4	[Brixton 1443
"London Scottish" Manufacturers & Engineers Ltd., 9 Richmond Road, Twickenham	[Richmond 626
Mendine Co. , 8 Arthur Street, E.C. 4. "Mendinique, Cannon, London"	[Bank 5873
Nieuwhof, Surie & Co. Ltd. (Casein), 5 Lloyds Avenue, London, E.C. 3	[Avenue 34 and 35
Oldroyd, Wm., & Sons Ltd., 9 Mincing Lane, E.C. 3	[Avenue 4978
Sheppy Glue & Chemical Works Ltd., 34 Mark Lane, E.C. 3	[London Wall 4820
S. Young & Co. Ltd.	..

GOGGLES—Triplex Safety Glass Co. Ltd., 1 Albemarle St., Piccadilly, W. 1 [Regent 1340

GUN GEARS—

Motor Macs Ltd., 35 Holdenhurst Road, Bournemouth	[Bournemouth 219
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HANGAR CONSTRUCTION—See Buildings.

HANGARS—See Buildings.

DIRECTORY OF MANUFACTURERS

HARDWOODS—See Timber.

HEATING AND VENTILATING—See Ventilating.

Kinnell, C. P., & Co., Ltd., Southwark Street, S.E. [Hop 372]
Sturtevant Engineering Co., Ltd., 147 Queen Victoria Street, E.C. [Central 7121]

HIGH AND LOW TENSION CABLES—

Kalker, E., & Co., Coventry. "Kalker Coventry" [Coventry 24x]

HOSE—

Dermatine Co. Ltd., 95 Neate Street, London, S.E. [Hop 31]
Harold Harley & Co., Becton Road, London, E.
Mestre & Blatge, 20 Store Street, London, W.C. [Museum 1220]

INSTRUMENTS (Anemometers, Altimeters, Barometers, Densimeters, Speed and Pressure Indicators, Manographs, Revolution Counters, Watches, etc.)—

Alexander, G. H., Coleshill Street, Birmingham
Alfred Graham & Co. (Loud Speaking Telephones), Crofton Park, London, S.E. [Sydenham 366]
British Wright Co. Ltd., 33 Chancery Lane, London, E.C. [Museum 494]
Brown Bros. Ltd., Great Eastern Street, London [E.C. [London Wall 6300]
Cowey Engineering Co. Ltd., Kew Gardens, Surrey [Richmond 447]
Foster Instrument Co., Letchworth, Herts. [Letchworth 26]
George Taylor (Brass Founders) Ltd. (O'Kill Pressure Indicators), All Saints St., Bolton.
General Aeronautical Co. Ltd., 30 Regent Street, London, S.W. 1 [Gerrard 280]
Goldsmiths and Silversmiths Co., 112 Regent Street, London, W. [Gerrard 9091]
Hasler Telegraph Works (Revolution Speed Indicators), Westminster, London, S.W.
Heenan & Froude Ltd. (Engine Testing Brakes), Worcester
Henry Hughes & Sons Ltd., Fenchurch Street, London, E.C. [Central 555]
Kelvin, Bottomley & Baird Ltd., 16-20 Cambridge Street, Glasgow
Mears Ear Phone Co. Ltd., 193 Regent Street, London, W. [Regent 5755]
Negretti & Zambra, 38 Holborn Viaduct, London, E.C. [City 1525]
Omnium Central, 175 Shaftesbury Avenue, London, W.C.
Rivers Engineering Co. Ltd., Cremorne Wharf, Lots Rd., Chelsea, S.W. [Kensington 3116]
Short & Mason Ltd., 46A Holborn Viaduct, E.C. [Walthamstow 180, Central 7014]
Simms Motor Units Ltd., Percy Buildings, Gresse Street, London, W. [Museum 2460]
S. Smith & Sons Ltd., 179-185 Great Portland Street, London, W. [Mayfair 6350]
Sperry Gyroscope Co. Ltd., 15 Victoria Street, London, S.W. [Victoria 7397]
The Cambridge Scientific Instrument Co. Ltd., Cambridge [Cambridge 642]
Weston Electrical Instrument Co., Ely Place, Holborn, E.C. 1
William Evans (Automatic Pistols), 63 Pall Mall, S.W. [Regent 4018]
W. G. Walker & Co., 2 Emery Hill Street, Victoria Street, London, S.W. [Victoria 1622]

INSURANCE—

Aviation Insurance Association, 1 Royal Exchange Avenue, E.C.
English & Continental Insurance Agency Ltd., 7 Wormwood Street, E.C. 3
Wheels & Wings Association Ltd., 33 King William Street, E.C. 4 [Central 3980]

JOINTING—

Bell's United Asbestos Co. Ltd., Southwark Street, London, S.E. [Hop 4040]
Dermatine Co. Ltd., 95 Neate Street, London, S.E. [Hop 31]

THE AVIATION POCKET-BOOK

LABELS—See Nameplates.

LIFE-SAVING BELTS, JACKETS, AND WAISTCOATS—

Boddy Life-Saving Appliances (1914) Ltd., 4 Broad Place, London, E.C., and 602 Tower Buildings, Liverpool	[London Wall 50
C. H. Holmes & Son, Albert Street, Manchester	..
H. H. Read, Falmouth, Cornwall	..
Robinson & Cleaver, Belfast and London	[Gerrard 1070

LUBRICATING OILS—

Brown Bros. Ltd., Great Eastern Street, London, E.C.	[London Wall 6300
Dick, W. B., & Co. Ltd., 90 Fenchurch Street, London, E.C. 3	[Avenue 7854
General Aeronautical Co. Ltd., 30 Regent Street, London, W.	[Gerrard 280
Premier Oil Extracting Mills Ltd., Hull. "Poem, Hull"	..
Sterns Ltd., 6 Finsbury Square, London, E.C.	[London Wall 3797
Wakefield, C. C., & Co., Wakefield House, Cheapside, London, E.C. 2	[Central 11305 and 13466

MACHINE TOOLS—

Alexander, George H., 83-84 Coleshill Street, Birmingham. "Viking"	[Central 1918
Brewster & Co., 11 Queen Victoria Street, E.C. 4. "Circumfuse, Cannon, London"	[City 768
Brookman & Co., Paddenswick Road, Hammersmith	[Hammersmith 226
Butler, J., & Co., Halifax	..
C. A. Hulton & Sons, 110 Bishopsgate, London, E.C.	[London Wall 1724
Coats Machine Tool Co., Thanet House, Strand, W.C. 2	[City 626
Drummond Bros. Ltd., Guildford	..
Evans, J., & Co. Ltd., Liverpool Street, Birmingham	..
E. W. Bliss Co., 2 Pocock Street, S.E.	[Hop 4340
Haighs Ltd., Oldham. "Haigh, Oldham"	[Oldham 1273
Henry, J. Brewster, & Co., 11 Queen Victoria Street, London, E.C.	[City 768
Jacobs, W. R. & A. J., Ltd., 94 Leonard Street, E.C. 2	[Central 5938
J. Sagar & Co. Ltd., Halifax, and 60 Watling Street, E.C.	[Bank 4 and 7
Joyce, C. N., Ltd., 131 Southwark Street, S.C.	[Hop 943
Lash, R., Ltd., 29 and 31 Portugal Street, W.C. 2, and at Letchworth, Herts.	..
Robinson, T., & Son Ltd., Rochdale	..
Wadkin & Co., Leicester. "Woodworker Leicester"	[Leicester 3614-15
Wallier, W. A., & Co., 38 Victoria St., Westminster. "Vilvalle, London"	[Victoria 3190
William Asquith Ltd., Park Lane, Halifax, England	..
Wilson Bros., Victoria Road, Leeds. "Mortising, Leeds"	[Leeds 723

MAGNETOS—

British Thomson Houston Co. Ltd., Rugby, and 83 Canon Street, E.C.	[City 2135
Fellows & Co., Cumberland Avenue, Park Royal, N.W. 10	[Willesden 1560-1
Lavalette & Cie., 175 Ave. de Choisy, Paris. "Allumanto, Paris"	[Ojob 1999
Meagher & Ratcliffe, 280 Deansgate Street, Manchester	..
Morris, Russell & Co. Ltd., Curtain Rd., E.C. 2. "Luminously, Phone"	[Wall 5443-4
Simms Motor Units Ltd., Percy Buildings, Gresse Street, W. 1	[Museum 2460
Smith, G. H., & Co. Ltd., 12 Mortimer Street, London, W.	[Museum 1282
The British Lighting and Ignition Co. Ltd. (Vickers Ltd.), 204 Tottenham Court Road, W. 1. "Vicksomag, Phone, London"	[Museum 430
The M-L Magneto Syndicate Ltd., Victoria Works, Coventry	[Coventry 1008-9

DIRECTORY OF MANUFACTURERS

METALS (Aluminium, Copper, Brass, Alloys, Ingots, etc.)—

Aerolite Piston Co. Ltd. (Aluminium Alloy Pistons), Hanover Court, Hanover Street, London, W.	[Gerrard 7865]
Alardux Co. (Aluminium flux), 23 Fleet St., E.C. 4	[City 8.6]
Aluminium Plant and Vessel Co., Point Pleasant, Wandsworth, S.W. 18 "Anaclastic, Wands".	[Putney 2353]
Anger Manufacturing & Supply Co. Ltd., Bank Chambers, Preston, Lancs.	..
Bernard Nicklin & Co. (Sheets), Smethwick, Birmingham	[Smethwick 224]
Birmingham Aluminium Castings (1903) Co. Ltd., Cambridge Street, Birmingham	..
British Aluminium Co. Ltd., 109 Queen Victoria Street, London, E.C.	[City 2676]
Broughton Copper Co. Ltd., Manchester	..
Bulls Metal & Melloid Co. Ltd., Yoker, near Glasgow	..
Charles Clifford & Son Ltd., Birmingham. "Clifford"	[Central 42-43]
Combined Metals & Reinforced Castings Co. Ltd., Point Pleasant, Wandsworth, London, S.W. "Overturned, Phone"	[Putney 2405]
Coventry Premier Ltd., Coventry. "Premier, Coventry"	[Coventry 514]
Delta Metal Co. Ltd., East Greenwich, London, S.E.	[Greenwich 123]
Edward Le Bas & Co., Dock House, Billiter Street, London, E.C.	[Avenue 5463]
Evans, Joseph, & Co. Ltd., Liverpool Street, Birmingham	[Central 733]
Eyre Smelting Co. Ltd., Barden Road, Tonbridge	..
Gabriel & Co., 4 and 5 A B Row, Birmingham. "Gabriel, B'ham"	[Central 1223]
Guthrie, J. B., & Son, 30 St Mary Axe, E.C. 3	[Avenue 1432]
Hoyt Metal Co. Ltd., The, 189 Hammersmith Rd., W. 6	[Hammersmith 1702]
J. H. Richards & Co. Ltd., Cato Street, North Saltley, Birmingham	..
London Aluminium Co. Ltd., 67A Westwood Road, Aston, Birmingham	[Fast 497]
London Die Casting Foundry Ltd., Tremlett Grove, 112 Junction Rd., N.	[Hornsey 2204]
Pritt & Co., 46 Fenchurch Street, London, E.C. 3	[Avenue 995, 996 and 7996]
Robert W. Coan (Aluminium Castings), 219 Goswell Road, London, E.C. "Krankases, Isling"	[City 5846]
Sale, H. B., Ltd., Constitution Hill, Birmingham	..
Samuel Mercer & Co., 198 Upper Thames Street, E.C. 4.	[City 6342]
T. H. Birkett & Sons, Marsh Street, Hanley, Staffs.	..
Vickers Ltd. (Aluminium Alloys and Steels), Broadway, Westminster, S.W.	[Victoria 6900]
Vowles Bros., Hall End, West Bromwich	..
William Mills Ltd. (Castings), Grove St., Birmingham	..
Yorkshire Engineering Supplies Ltd., near Wortley Rd., Leeds	[Central 3927]

METALS (Copper and Brass Rods, Tubes, Sheets, Wire)—

Blackburn & Co., Stephen Street, Tottenham Court Road, W. 1	[Museum 650]
Clifford, Charles, & Son Ltd., Fazeley Street, Birmingham	[Central 3634]
Hatton & Co., Upper Thames Street, E.C.	[Bank 5062]
Johnson & Burgess Ltd. (Yellow Metal Sheet), 9 Quay, Swansea	..
Pritt & Co., 46 Fenchurch St., E.C. 3. "Poetry," Fen., London	[Avenue 995-6]
Rollet, H., & Co., Metal Warehouses, 34-36 Rosebery Avenue, E.C. 1	[Holborn 2620]
S. Sansum & Co., Alexandra St., Wolverhampton	[Phone 1115]

METALS (Steel Plates, Sheets, Bars, Rods, Castings, etc.)—

Burys & Co. Ltd., Sheffield	[Central Sheffield 4]
Dunford & Elliott, Attercliffe Wharf, Sheffield	[Central 1165, 1713, 2821]
Firth, Thos., & Sons, Sheffield. "Firth, Sheffield"	[Sheffield 3230 to 3237]

THE AVIATION POCKET-BOOK

METALS, ETC. (*continued*)—

Guthrie & Son, 30 St Mary Axe, E.C. 3. "Busiris Led," London	[Avenue 1432]
Marsh Bros. & Co. Ltd., Sheffield	..
Nicklin, Bernard, & Co., Birmingham. "Bernico, Birmingham"	[Smithwick 224]
Park Gate Iron and Steel Co. Ltd., Rotherham, England	..
Vickers Ltd., Broadway, Westminster, London, S.W.	[Victoria 6900]
W. T. Flather Ltd., Sheffield	..

METAL PARTS AND FITTINGS (also refer to Aviation Accessories)—

Accles & Pollock Ltd., Oldbury, Birmingham. "Accles, Oldbury"	[Oldbury 111]
Aero Parts Manufacturing Co. , 199 Piccadilly, London, W. 1	[Gerrard 6003]
Aeroplane General Sundries Co., 69-70 Fulwood House, Fulwood Place, Holborn,	..
W.C. 1. "Zeppiskout, Holb., London"	[Holborn 4959]
A.G.S. Mfg. Co., 4 and 5 Norfolk Street, London, W.C. 2	[Central 1446]
Aircraft Construction Co., Beckton Road, E. 16	[East 1300]
Aircraft Supplies Co. Ltd., Ascol House, 125 Long Acre, W.C. 2	[Gerrard 276]
Aluminium Plant & Vessel Co. Ltd., Point Pleasant, Wandsworth, London, S.W. 18.	..
"Anaclastic, Wands., London"	.. [Putney 2353]
Arnott & Harrison Ltd., Hythe Road, Willesden Junction, N.W. 10	[Willesden 2207]
Bayliss, Jones & Bayliss Ltd., Wolverhampton (Bolts and Nuts).	[Wolverhampton 1041]
Birch Aircraft Co., 169-171 High Road, Willesden Green	..
Birmingham Guild Ltd., 45 Great Charles St., Birmingham	[Central 3705]
Blackburn Aeroplane & Motor Co. Ltd. , Olympia, Leeds	[Roundhay 345]
British Gold Shell Ring Co. Ltd., Inverness Rd., Hounslow, London	[Hounslow 254]
British Metal (Kingston) Ltd., Kingston-on-Thames	..
Brown Bros. Ltd., Great Eastern Street, London, E.C. 2	[London Wall 6300]
Bulpitt & Sons Ltd., Birmingham	..
Clews & Sons, 195 Aston Road, Birmingham	..
Cole, W., & Son , Hammersmith Rd. London, W. 6. "Imota, London"	[Hammersmith 1413]
Combined Metals & Reinforced Casting Co. Ltd., Wandsworth, London,	..
S.W. 18. "Overturned, Phone, London"	.. [Putney 2405]
Coventry Premier Ltd., Read Street, Coventry. "Premier, Coventry"	[National 514]
Durke, H., Chitty Street, Tottenham Court Road, London, W. 1	..
Evans, J., & Co. Ltd., Liverpool St., Birmingham. "Adept, Birmingham"	[Central 1774, 733]
Gabriel & Co., 2 and 4 B Row, Birmingham. "Gabriel, Birmingham"	[Central 1224]
Gilbert, W. V., & Co., 7 Princes Street, Westminster, S.W.	[Victoria 7089]
Guthrie, J. B., & Son, 30 St Mary Axe, E.C. 3. "Busiris, Led, London"	[Avenue 1432]
Harris & Sheldon Ltd., Stafford Street, Birmingham	..
Harrison & Co., Bradford Street, Birmingham. "Remarkable, B'ham."	[Midland 675]
Heavy Stampings Ltd., Middlesbrough. "Stampings, Middlesbrough"	[Middlesbrough 291]
Hewson Mfg. Co., Newnan Yard, Newman Street, W. 1	[Museum 1477]
Jacobs, W. A. & R. J., Ltd., 94 Leonard Street, E.C. 2	[Central 5038]
Jones Brothers & Co. Ltd., Wolverhampton	..
Kroll & Co., Bayham Place, London, N.W.	.. [North 1402]
London Aluminium Co. Ltd., 57A Westwood Road, Aston, Birmingham	.. [East 497]
London Sheet Metal Working and Welding Co., 21 Risinghill St., Pentonville, London, N.	..
Mann, Egerton & Co. Ltd., 177 Cleveland Street, London, W. 1	[Museum 70]
Meerlo Engineering Co. Ltd. , Forest Lane, Stratford, E. 15	[Stratford 973]
Meteor Mfg. Co. Ltd., 72 Gray's Inn Road, London, W.C. 1	[Holborn 4632]
Minchin Engineering Co. Ltd., Penrhyn Road, Kingston-on-Thames	[Kingston 97]
Monk Engineering Co., High St., Coventry. "Assistance, Coventry"	[Coventry 807]

DIRECTORY OF MANUFACTURERS

METAL PARTS AND FITTINGS (*continued*)—

Moss, W. , High St., New Oxford St., W.C.2. "Airobilmos-Phone, London"	[Gerrard 6731
Motor Macs Ltd. , Holdenhurst Road, Bournemouth	[Bournemouth 219
Mountford, Fredk., Ltd. , Lifford, Birmingham.	[Kings Norton 261
Omnium Central , 29 Red Lion Sq., W.C.1. "Omnacentum, Westcent, London"	[Holborn 185
Pulvo Engineering Co. Ltd. , Dane Street, Holborn, W.C.1. "Pulvipult"	[Holborn 410
Randall, J. H., & Son , Paddington Green, W.2	[Paddington 6340-1
Rivers Engineering Co. Ltd. , 27 Lots Road, Chelsea, S.W.10.	[Kensington 3116
Robertson, J. H., & Co. , 1 Albemarle Street, London, W.1	[Regent 3886
Robson, S. T., Ltd. , 275 Coventry Road, Birmingham.	[Victoria 432
Rotax Motor Accessories Co. , Willesden Junction, N.W.10	[Willesden 2480
Rubery, Owen & Co. Ltd. , Darlaston. "Roofs, Darlaston"	[Darlaston 87
Sankey, Joseph, & Sons Ltd. , Wellington, Shropshire	[Wellington 66
Selsdon Aero & Engineering Co. Ltd. , 1 Albemarle Street, Piccadilly, W.1	[Regent 1181
S. Mercer & Co. , 198 Upper Thames Street, London, E.C.	[City 6342
Smith, A. W., & Co. , London Road, Barking, E.	[East Ham 519
S. Sherman & Son , 57 New Compton Street, London, W.C.	[Gerrard 4939
Sun Electrical Co. Ltd. , 57-59 Neal St., W.C.2 "Secabilis Ox, London"	[Gerrard 2291
Thompson Bros. Ltd. , Bradley, Bilston. "Thompson Bros., Bilston"	[Bilston 10
W. H. Briscoe & Co. Ltd. , 51-53 Park St., Birmingham. "Brisk"	[Central 550
Whiteman & Moss Ltd. , 15 Bateman St., W.1. "Whitomoss, Ox, London"	[Gerrard 6824
Whitfield Aviation Ltd. , 10 Dane Street W.C.1	[Holborn 409
Williams & Williams Ltd. , Chester. "Reliance, Chester"	[Chester 765
Woodside Engineering Co. Ltd. , North Woodside Rd., Glasgow ["Encelage," Glasgow	
Wooler Engineering Co. Ltd. , Old Oak, Common Lane, Willesden Junction, N.W.10	[Willesden 117
Wycombe Aircraft Constructors Ltd. , 57 London Rd., High Wycombe	[High Wycombe 225

MODELS AND PARTS—

A. E. Jones Ltd. , 97 New Oxford Street, London, W.C.	..
A. W. Gamage Ltd. , Holborn, London, E.C.	[Holborn 2760
Edwin Cooper & Co. Ltd. , Lower Kennington Lane, London, S.E.	[Hop 3807
Littleover Motors , Derby	..
T. W. K. Clarke & Co. , High Street, Hampton Wick	[Kingston 869
W. G. Evans & Sons , Stanhope Street, Euston Road, London, N.W.	..

MOTOR VEHICLES—

Arrol Johnston Ltd. , Dumfries. "Mocar, Dumfries"	[Dumfries 281-282
Crossley Motors Ltd. , 50 Page St., W'minster, S.W.1, & Manchester	[Victoria 7240, City 4611
Mann, Egerton & Co. Ltd. , 379-381 Euston Road, London, N.W.1	[Museum 70
Oakley Ltd. , 28 Duke Street, Piccadilly	[Gerrard 2242
Standard Motor Car Co. , Coventry. "Flywheel Coventry"	[Coventry 530

NAMEPLATES AND LABELS—

British Metal (Kingston) Ltd. , Kingston-on-Thames	..
Endolithic Manufacturing Co. Ltd. , 61½ Fore Street, London, E.C.2.	[London Wall 3421
The Clegg Metal Engraving Co. , Chatsworth Works, Worthing	..
The Hughes Label Co. Ltd. , Titchfield Works, Enfield	[Enfield 543

OIL—See Lubricating Oils.

OIL CANS—Kaye, Joseph, & Sons Ltd., Leeds, and 93 High Holborn, London, W.C.
[Holborn 1847

OXYGEN WELDING—See Welding.

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PACKING—

Bell's United Asbestos Co. Ltd., Southwark Street, London, S.E.	[Hop 4040]
Cape Asbestos Co. Ltd., 23 King Street, E.C. 2	[City 598]
Dermatine Co. Ltd., Neate Street, London	[Hop 31]

PAINTS, ENAMELS, ETC.—See Varnishes.

PARACHUTES—

C. G. Spencer & Sons Ltd., 56A Highbury Grove, N. 5	[Dalston 1893]
E. R. Calthrop's Aerial Patents Ltd., Eldon Street House, Eldon Street, E.C. 2	[London Wall 3266-67]

PETROLS, TAPS, COCKS, FITTINGS, FILLERS, PIPES, ETC.—See Accessories.

PISTON RINGS—

Allen & Simmons, Reading	..
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PLUGS—See Sparking Plugs.

PLYWOODS—See Timber.

POWER PRESSES AND DIES—Bliss, E. W., & Co., 7 Pocock Street, Blackfriars

Road, London, S.E. 1. "Blissdon, Sedist, London"	[Hop 4340]
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PRESSWORK—See Sheet Metal Workers.

PROPELLERS—(Also see Aeroplane Manufacturers).

Aircraft Construction Co., Beckton Road, E. 16.	[East 1300]
Austin Motor Co. Ltd., Northfield, Birmingham	[King's Norton 230]
A. V. Roe & Co., Miles Platting, Manchester	..
Barker & Co. Ltd., 66-68 South Audley Street, W.	[Mayfair 7110-7114]
Beardmore, Wm., & Co. Ltd., Dalnair	..
Betjemann & Sons Ltd., 36 Pentonville Road, N.	[North 2992]
Bianco Ltd., Tottenham Court Road, W.C.	[Museum 208]
Blackburn Aeroplane & Motor Co. Ltd., Olympia, Leeds	[Roundhay 345]
Boulton & Paul Ltd., Rose Lane, Norwich. "Aviation, Norwich"	[Norwich 851]
British & Colonial Aeroplane Co. Ltd.	[Bristol 3966]
Brush Electrical Engineering Co. Ltd., Loughborough	[624]
Cohen, B., & Sons Ltd., 1-19 Curtain Road, E.C.	[Wall 3729]
Courtney Pope & Co. Ltd., 8A Caledonian Road, N.	[Central 8654]
C. F. Kearley Ltd., 4 Gt. Marlborough St., W. [City 8742, Gerrard 0937, Hammersmith 467	
Darracq Motor Engineering Co. Ltd., Townmead Road, Fulham, S.W.	..
Davidson Aviation Co. Ltd., 231 Hammersmith Road, S.W.	[Hammersmith 1992]
Davies, Bennett & Co., Horseferry Road, S.W. 1	[Victoria 1212 and 707]
Dixon Bros. & Hutchinson, Woolston, Southampton	[389]
Dove Bros. Ltd., Cloudeley Place, Islington, W.	[North 1804]
Elora Propeller Co., 11 and 12 Surbiton Park Terrace, Kingston-on-Thames [Kingston 672	
Falcon Aircraft Co., 113 Tottenham Road, Holloway, N.	[Hornsey 910]
Farrington Engineering Co., 39 Victoria Street, S.W. 1	[Victoria 1338]
Frederick Sage & Co., 58-62 Gray's Inn Road	[Holborn 2004]
General Aeronautical Co. Ltd., 30 Regent Street, London, S.W.	[Gerrard 290]
George Trollope & Sons and Colls & Sons Ltd., 77 Grosvenor Rd., S.W. 1	[Victoria 1971]
Graham-White Aviation Co. Ltd., Hendon, N.W. 9	[Kingsbury 129]
Handley Page Ltd., 110 Cricklewood Lane, N.W. 2. "Hydrophid, Crickle"	[Hampstead 7420]

DIRECTORY OF MANUFACTURERS

PROPELLERS (*continued*)—

Hermann & Phillips, Acton Street, Kingsland Road, N.E.	[Dalston 1590]
Integral Propeller Co. Ltd., Edgware Road, The Hyde, Hendon, N.W. 9	[Kingsbury 104]
John Brinsmead & Sons Ltd., 18-22 Wigmore Street, W.	[Mayfair 1243 and 3524]
J. Curtiss & Son, Oxford Row, Leeds	[453]
Joseph Evans & Sons, Salisbury House, E.C.	[Central 796]
J. Samuel White, 28 Victoria Street, S.W. 1	[Victoria 4507 and Cowes 3]
John Thompson & Son, Wood Street, Peterborough	[35]
Lang Propeller Ltd., Weybridge. "Aerosticks, Weybridge"	[Weybridge 520-521]
Lucraft & Westcott, Albert Road, Wood Green, N. 22	[Hornsey 1807]
Mann, Egerton & Co. Ltd., Norwich. "Motors, Norwich"	[Norwich 482]
Maple & Co., 149 Tottenham Court Road, W.	[Museum 7000]
Marsh, Jones & Cribb Ltd., Leeds	[Leeds 594]
Messenger & Co. Ltd., 122 Victoria Street, S.W. 1	[Victoria 1209]
Morris & Co., 28 Granville Place, Orchard Street, W.	[Gerrard 2431]
Oddy, W. D., & Co., Leeds. "Aircscrews, Leeds"	[Central 291]
Ogilvie & Co., Mildmay Ave., Newington Green Road, N.	[Dalston 1388]
Parnall & Sons, Livart Street, Bristol	..
Portholme Aerodrome Ltd., St John's Street, Huntingdon	[26]
Prestige & Co. Ltd., Cambridge Wharf, Grosvenor Road, S.W.	[Victoria 6630 and 1812]
Rippers Ltd., Castle Hedingham, Essex	[9]
Ruston Proctor Ltd.	[Lincoln 581, London City 5145]
Sage, F., & Co. Ltd., Peterboro'	..
Shapland & Petter, 62 Oxford Street, W.	[Museum 1434, Barnstaple 9]
Short Bros., 29-30 Charing Cross, S.W.	[Regent 378 and Eastchurch 9]
Stanley Aviation Co. , 67 Kingsland Road, E. 2	[City 5347]
Tamworth, Hindley & Co., 26 Buckingham Gate, S.W.	[Victoria 5745]
Thos. Horsman, 10-12 Mark Lane, Leeds	[900]
Tibbenham's Aviation Co., Portland Road	[Ipswich 505]
Trevor, Page & Co., Exchange Street, Norwich	[National 238]
T. W. K. Clarke & Co. Ltd., High Street, Hampton Wick	[Kingston 869]
W. E. Blake Ltd., Stevenage Road, Fulham, S.E.	[Putney 231]
Watling, R. S., & Sons, The Maltings, Great Yarmouth	[130]
Westland Aircraft Works, Yeovil. "Aircraft, Yeovil"	[Yeovil 129]
White Allom & Co. Ltd., 15 George Street, Hanover Square, W.	[Gerrard 5716]
Wolsley Motors Ltd., York St., W'minster, S.W. 1	[Vict. 6220 and B'ham Cent. 4561]
Wm. Willett, Sloane Square, S.W.	[Kensington 4600]

PULLEYS, SHAFTING, BEARINGS—

Smith & Grace Ltd., 35 Queen Victoria Street, E.C.	"Works, Thrapston" [City 9531]
Walber, W. A., & Co., 38 Victoria Street, S.W. 1	"Vilvalle, London" [Victoria 3190]

RADIATORS—

Auto Radiators Ltd., 8 Manette Street, London, W.	[Regent 2362]
Barimar Ltd., 10 Poland Street, W. 1	"Bariquamar, Reg. London" [Gerrard 3173]
Doherty Motor Components Ltd., Earl Street, Coventry	"Circulate Coventry" [Coventry 228]
Gallay Radiator Co. Ltd., 198 Great Portland Street, W. 1	[Mayfair 4826]
J. H. Randall, Green Street, Paddington, London, W.	[Paddington 6340-1]
London Sheet Metal Co., 21 Risinghill Street, Pentonville, London, N.	..
Midland Motor Radiator Co., Ashton Road, Birmingham	"Radiator, Birmingham" [Central 705]

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RADIATORS (*continued*)

Motor Radiators Ltd., Hanway Street, Oxford St., London . . . [Hammersmith 1134]
 Randall, J. H., & Son, Green Street, Paddington, W. 2 . . . [Paddington 6340-41]
 Randle Radiator Co., Cheylesmore, Coventry

RUBBER CORD (Bralded)—Whitely Exerciser Ltd., 35 Southwark Bridge Road,
 London, S.E. [Central 12215]

RUBBER TUBING AND ACCESSORIES—Hancock, James Lyne, Ltd., 226 Goswell
 Road, London, E.C. 1. "Masticator, Isling, London" . . . [City 3811-12]

SAFETY BELTS—

Aircraft Supplies Co. Ltd., 125 Long Acre, W.C. 2 . . . [Gerrard 276]
 Holmes, C. H., & Son, 38 Albert Street, Manchester. "Semlob, Manchester" [City 4432]

SCHOOLS—See Flying Schools.

SEWING MACHINES—Singer Sewing Machine Co. Ltd., 17 Chiswell St., Finsbury,
 E.C. 1 [City 8510]

SHEET METAL WORKERS—

Accles & Pollock Ltd., Oldbury, Birmingham. "Accles, Oldbury" . . [Oldbury 111]
 Anger Manufacturing & Supply Co. Ltd., Bank Chambers, Preston, Lancs . .
 Barimar Ltd., 10 Poland Street, London, W. [Gerrard 8173]
 Birmingham Guild Ltd., Gt. Charles Street, Birmingham . . . [Central 3750]
Blackburn Aeroplane and Motor Co. Ltd., Olympia, Leeds . . . [Roundhay 345]
 British Metal (Kingston) Ltd., Kingston-on-Thames . . . [Kingston 579]
 Brooks, J. B., & Co. Ltd., Criterion, Birmingham
 Combined Metals and Reinforced Casting Co. Ltd., Wandsworth, S.W. . [Putney 2405]
 Evans, Joseph, & Co. Ltd., Liverpool Street, Birmingham . . . [Central 373]
 Ewart & Son Ltd., 346 Euston Rd., N.W. [Museum 2570]
 Fredk. Braby & Co. Ltd., 352-364 Euston Road, London, N.W. . . [Museum 3052]
 Gabriel & Co., 4 and 5 A B Row, Birmingham. "Gabriel, Birmingham" [Central 1923]
Jacobs, W. A. & A. J., Ltd., 94 Leonard Street, E.C. 3 . . . [Central 5938]
 Jones Bros. & Co. Ltd., Wolverhampton
 J. B. Guthrie & Son, 38 St Mary Axe, E.C. 3. "Busiris Led, London" [Avenue 1432]
 Kensington Motor Sheet Metal Co., Andsell Street, High Street, Kensington, W.
 [Western 6792]

Kroll & Co., Bayham Place, Camden Town, London, N. [North 1402]
 London Aluminium Co. Ltd., Westwood Road, Aston, Birmingham . [East 497 B'ham]
 Musgrove & Green Ltd., Bromsgrove St., Birmingham
 Nicholls & Lewis Ltd., 16 Princip St., B'ham. "Colpressed, B'ham" [Central 7188]
Pearce, G. W., & Sons Ltd., London Works, Whitehouse Street, Aston, Birmingham
 [East 847]

Pulvo Engineering Co. Ltd., 10 Dane Street, W.C. [Holborn 400]
 Randall, J. H., & Son, Green Street, Paddington [Paddington 6340]
 Randle Radiator Co., Cheylesmore, Coventry
 Rubery, Owen & Co. Ltd., Darlaston. "Roofs, Darlaston" . . [Darlaston 87]
 Sankey, Joseph, & Sons Ltd., Wellington
 S. Sherman & Son, 57 New Compton Street, London, W.C. . . . [Gerrard 4939]
 Skerne Works Ltd., Darlington. "Wheels, Darlington" . . . [Darlington 2612]
The Acetylene Corporation of Great Britain Ltd., 49 Victoria Street, S.W. 1 [Vic 4830]
The Selsdon Aero & Engineering Co. Ltd., Imperial House, Kingsway, W.C. 2 [Regent 1181]

DIRECTORY OF MANUFACTURERS

SHEET METAL WORKERS (*continued*)—

Williams & Williams Ltd., Chester	[Chester 560
W. H. Briscoe & Co. Ltd., 51 and 52 Park Street, Birmingham	[Central 550

SPARKING PLUGS—

Apollo Manufacturing Co., Moseley Street, Birmingham	..
Brown Bros. Ltd., Gt. Eastern Street, E.C. 1	[London Wall 6300
C. C. Sparking Plug Co., 145 Queen Victoria St., E.C. 4	..
Forward Motor Co., Summer Row, Birmingham	[Central 6250
Hobson Manufacturing Co., 29 Vauxhall Bridge Road, S.W. 1	[Victoria 4670
Lodge Sparking Plug Co. Ltd., Rugby. "Igniter, Rugby"	[Rugby 235
Morris, Russell & Co. Ltd., 75 Curtain Road, E.C. 2	[London Wall 5113
P. C. Jette's (Joly), 62 St Helens Park Road, Hastings	..
Ripault, Leo, & Co. Ltd. (Oleo Plugs), 64A Poland Street, W. 1	Gerrard 7758
Sphinx Manufacturing Co., Birmingham	..

SPRINGS—

Dart Spring Co. Ltd., Overend, West Bromwich. "Dart"	[West Bromwich 322
Gabriel & Co., 4 and 5 A B Row, Birmingham. "Gabriel, Birmingham"	[Central 1223
Herbert Terry & Sons Ltd., Redditch. "Springs."	[Redditch 61
Tubbs, Lewis & Co., Noble St., E.C. 2. "Elastics, London"	[City 22

TANKS (Petrol, etc.)—See Sheet Metal Workers.

TAPES, WEBS, AND SMALLWARES—See Fabrics.

MacLennan, J., & Co., 30 Newgate Street, E.C. 1, and at Glasgow	[City 3115
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TELEPHONES—

London Telephone Co. Ltd., West Dulwich, S.E. 4	[Sydenham 1067
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TESTING MACHINES—

Avery, W. & T., Ltd., Birmingham	..
Heenan & Froude Ltd., Worcester and Caxton House, S.W. 1	[Victoria 687

TIMBER (Aeroplane)—

Brown, R. F. & F. W., Wollaton, Notts.	[Nottingham 1526
C. B. N. Snewin & Sons Ltd., Black Hill, Hatton Garden, London, E.C.	[Holborn 5000, and Central 8754
C. Boss & Co., 634 Royal Liver Buildings, Liverpool	..
Courtney, Pope & Co., Ltd., 8A Caledonian Road, N.	[Central 8654
C. Noel Legh & Co., Miller's Bridge, Bootle, Liverpool	..
Engineering Timber Co. Ltd., 9 Victoria Street, S.W. 1	[Victoria 5073, 4210
Evans & Son, Williams Mews, Stanhope Street, London, N.W.	..
Fox, Elliott & Co., G.W. Docks, Plymouth. "Baltic, Plymouth"	[Plymouth 1217
Hopton & Sons, George Street, Euston Road, N.W. 1. "Hoptons, London"	[Museum 406
Hopton, G., & Co., Manchester Street, King's Cross, W.C. 1	[North 3426-7
J. Gliksten & Son Ltd., Carpenters Road, Stratford, London, E.	[East 3371
John Remer & Co., 14 Dale Street, Liverpool	..
Owen, Joseph, & Sons Ltd., Borough High Street, S.E. 1. "Bucheron, London"	[Hop 3811
R. Cattle, 27 Wybert Street, Stanhope Street, London, N.W.	[Museum 1814
Siberian & General Trading Co. Ltd. (Plywood), 1-3 Lennard St., E.C. 2	[London Wall 3577
The London Plywood Manufacturing Co. Ltd., 384 Old Street, E.C. 2	..
Venesta Ltd. (Plywoods), 1 Great Tower Street, London, E.C.	[London Wall 4760

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TIMBER (*continued*)—

TIMBER DRYING—

Kinnells, C. P., & Co. Ltd., Southwark St., S.E.	[Hop 372]
Nieuwhof, Surie & Co. Ltd. (Casein), 5 Lloyds Avenue, E.C. 3	[Avenue 34 & 35]
Ruston Proctor Ltd., Lincoln	..
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